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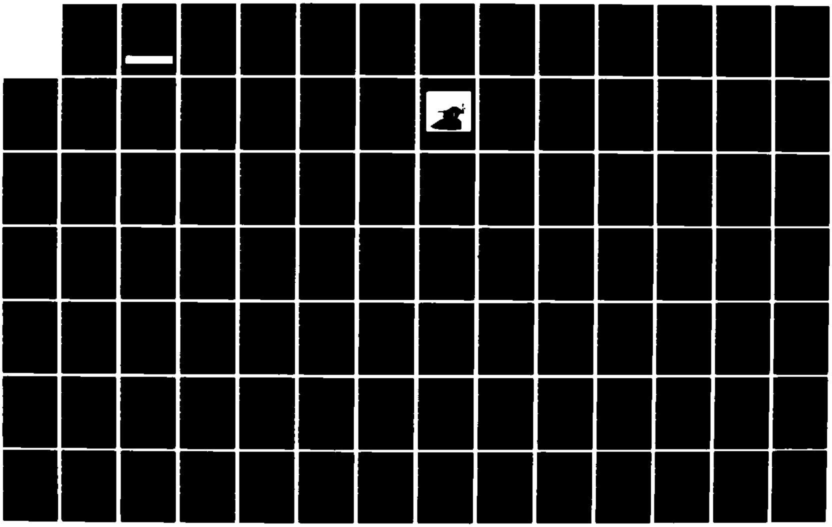

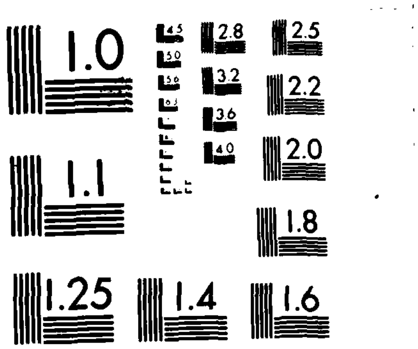

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Technical Report NAVTRAEQUIPCEN 81-C-0105-9

VISUAL AND PART-TASK MANIPULATIONS FOR TEACHING SIMULATED CARRIER LANDINGS

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[illegible] quasi-transfer-of-training study was conducted with 36 flight-na[illegible] [illegible] to investigate a segmentation method of part-task training, and [illegible] methods of visual augmentation, for teaching simulated carrier landings. [illegible] visual enhancement involved adding two types of descent rate information ([illegible] RATE and COMMAND) to the FLOLS display. The other visual enhancement was enlargement of the FLOLS display. The experimental sequence [illegible] of 30 training trials with instructional feedback under a [illegible] experimental condition, followed by 30 test trials with no [illegible] feedback under the criterion condition (whole task with con[illegible] [illegible] small FLOLS).

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The segmentation method of part-task training used here was not as effective as was whole-task training. However, the part-task manipulation was extreme, and apparently was less effective because students were unable to practice some critical dimensions of the task. Nevertheless, part-task subjects did learn some skills that could be applied to the whole task. There is also a realistic possibility that some adjustments in the way the part-task procedure is set up would further enhance its effectiveness.

There was no general performance or training benefit from the RATE or the COMMAND displays. There were, however, some minor differential transfer effects resulting from the use in training of the CONVENTIONAL, RATE, and COMMAND displays. These might be useful in special remedial situations and may have some implications for the way these displays are introduced into the fleet as permanent guidance systems. For the present, it is suggested that the RATE and COMMAND display should not be introduced to pilots until they have become carrier qualified with the conventional FLOLS.

Possibly the most important finding of this study is that transfer from a large to a small FLOLS has no general detrimental effects. Representation of the FLOLS is a critical element of a carrier landing trainer, and could add substantially to the cost of the simulator. The fact that a larger FLOLS can provide satisfactory training will permit a less expensive approach to simulating the FLOLS. A possible difficulty with AOA control in early transfer was noted, but sufficient care in training should overcome this potential problem.

PREFACE

I extend my appreciation for the technical support provided by the following individuals associated with the Visual Technology Research Simulator program: from the Naval Training Equipment Center (Code N-732), Walter Chambers, Dr. Dennis Wightman, Bruce Riner, Patricia Daoust and Ed Ades; and from Essex Corporation, Dr. Gavan Lintern, Dr. Daniel Westra, Brian Nelson and Karen Thomley.

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SECTION I

INTRODUCTION

The approach to and landing on an aircraft carrier is a demanding task for any pilot and is one of the most dangerous he can be called upon to perform. The flight skills required for the task are acquired primarily by repetitive practice on a land-based runway and in a simulator designed to represent the criterion device and environment as closely as possible. While many factors contribute to the carrier-landing problem (e.g., poor visual cues, limited landing area, deck movement), perceptual judgments of vertical position on the flight path and subsequent motor responses are the most critical factors in a carrier approach (Gold, 1974; Durand and Wasicko, 1967). The objective of this research is to examine methods of improving simulator training effectiveness for the critical features of the carrier landing task.

Flight simulators have long been viewed as substitute airplanes. They are designed to represent the criterion device and environment to a reasonable degree of fidelity. The goal of most flight simulators is to increase training effectiveness in a safe and cost-effective manner. However, increased training effectiveness is often considered to be almost synonymous with increased simulation realism (Bunker, 1978).

While technological advances such as high detail and large field-of-view visual systems, motion systems and G-seats have increased realism, the major emphasis should be to optimize skill development in the simulator. Thus, a more appropriate research thrust would focus on principles of learning rather than development of technology as a path to optimizing skill development in the simulator.

Emphasis on principles of learning rather than available technology to increase simulator effectiveness reflects an awareness that an appearance of correspondence with reality rather than an actual correspondence may be sufficient for training (Staples, 1978). Even an appearance of correspondence with reality may be unnecessary, and it may be adequate to provide the necessary information for teaching certain flight objectives in many different ways (Caro, 1977). Furthermore, departures from reality may not only be less expensive but may be more effective for teaching flight skills (Hennessy, Lintern, and Collyer, 1981). For example, the application of a simulator's Freeze/Reset feature (freeze pilot in midflight to give feedback and then reset on course) to teach the carrier-landing task (Hughes, Lintern, Wightman, Brooks, and Singleton, 1981), and the use of unconventional displays (e.g., outside viewpoint from behind the aircraft, or flight instruments only) to teach basic flight tasks (Hennessy et al., 1981) have been examined in recent experiments.

Stark (1982) has also suggested that today's advanced simulation technology be applied to support individual training problems. Stark suggests that difficult and important skills and skill components should be trained outside the whole-task context in low cost but high-fidelity training settings designed to mediate only that information relevant to a specific task or task component.

The current study is an extension of this concept and philosophy of training and will explore the usefulness of part-task instruction and two methods of display augmentation for teaching the carrier-landing task.

PART TASK TRAINING

Part-task training is generally regarded as practice on a portion of the whole task prior to practice on the whole task. One part-task approach is to identify the specific components of the whole task that are either difficult to learn or are critical to the acquisition of the task. These components can then be subjected to extensive practice before the total skill is learned. This procedure may lead to a more rapid acquisition of the task and possibly better transfer to the whole task. A modest amount of transition training would almost certainly be required to coordinate component skills, but extensive practice in a high fidelity, whole-task simulator would probably be unnecessary (Adams and Hufford, 1962).

Although some basic research has been done on part-task versus whole-task training, little has been undertaken with multi-dimensional perceptual-motor tasks and even less with operationally relevant tasks such as carrier-landings. Nevertheless, the basic research provides some insight into the application of part-task training to operational tasks.

Briggs and Waters (1958) used a pitch-and-roll tracking task to study the value of task component interaction in part- versus whole-task training. They found that practice on individual components was progressively less beneficial, as the degree of component (part) interaction was increased in the transfer or whole task.

Naylor and Briggs (1963) used a prediction type task to study the effects of task complexity and task organization in part- versus whole-task training. They found that part-task training was less effective than whole-task training for a criterion task of high difficulty and high component interaction.

Schendel, Shields and Katz (1978), in a review of the literature on variables known to affect the retention of learned motor behaviors, states the effectiveness of part-task as opposed to whole-task training methods varies with the difficulty of a task's independent subtasks and the degree to which the subtasks are interrelated. They stated that:

> "It generally is easier to learn simple to moderately difficult tasks using whole-training methods rather than part-training methods, whereas the opposite is true for more difficult tasks.
>
> "Tasks requiring high coordination and timing of their serial-motor components are learned faster using whole-training methods. In contrast, part-training methods tend to be more effective for tasks that can be divided in meaningful independent subtasks.
>
> "There appears to be an interaction between task difficulty and task organization that influences the relative effectiveness of part- and whole-training methods. Thus, training for tasks of high organization becomes increasingly more effective with whole practice as task difficulty increases. On the other hand, training for tasks of low organization is increasingly improved by part practice as task difficulty increases."

The carrier-landing task is difficult and requires considerable coordination of motor components. The basic research indicates that a part-task approach to training is not advisable in this type of situation. Briggs and Waters (1958) suggested that this is so because subjects are unable to learn how specific components of the task interact when the components are practiced separately. Concurrent practice is needed to learn how specific components interact in a highly organized task. Briggs and Naylor (1962) also argued that similarity to the transfer task and the opportunity to develop efficient timesharing behavior (concurrent practice of task components) are both needed for effective learning on complex tasks. Thus, part-task training may be inefficient in a difficult task with interdependent components for two reasons. The training and transfer tasks are dissimilar, but more important, there is no opportunity to learn to timeshare interacting task components. Thus, a part-task training strategy that allowed efficent timesharing and learning of subtask interactions would provide efficient transfer for a difficult task with interdependent components. The carrier-landing task is suitable for testing this hypothesis and the following description of the task will be used to suggest a possibly effective approach to part-task training.

For a carrier approach (Figure 1), the pilot attempts to follow a designated glideslope (oblique path) so that a hook attached to the tail of the aircraft will contact the landing deck midway between the second and third of four arrestment wires (cables laid across the landing deck). The wires are at different distances from the ramp (threshold of the landing deck). Under the aircraft's momentum the hook travels forward to snag the third wire for a trap (arrested landing). The first or second wire may be caught on a low approach and the fourth on a high approach. Very low approaches can result in a ramp strike (collision with the stern of the carrier) while high approaches can result in a bolter (a missed approach because of touchdown beyond the wire arrestment area).

The pilot must not only maintain a precise glideslope but also must simultaneously maintain the correct angle of attack (angle at which the wing moves through the air), airspeed, vertical velocity, and lineup with the landing area. If the pilot maintains position and velocity errors within acceptable limits, he will execute a successful touchdown and trap (Gold, 1974). Although all task dimensions are essential to safe and successful carrier-landings, glideslope control is the most critical and difficult.

The part-task training method proposed here is to freeze the aircraft at a point along the carrier approach so that the subject cannot fly forward to land on the carrier. The simulated aircraft will be permitted to move along all except its lateral axis. The rationale for this part-task strategy is outlined below:

1. Subjects will have intensive glideslope tracking practice in a less complex task. Briggs and Waters (1958) suggested a simplification method of part-task instruction may be appropriate for a task with interdependent components. Holding (1962) also argues that positive transfer can occur following task simplification as long as proper information is provided for error detection and correction.

2. All piloting tasks except lateral control will be timeshared. This will provide knowledge of interaction of the more critical components. The lack of lineup practice was not considered serious. Lineup control does not constitute a major problem in the carrier landing and the experimental task will require appropriate left and right stick responses to maintain heading lined up with the landing deck. Thus, a few trials of transition training in the whole task is expected to be sufficient to coordinate the skills essential for lateral control.

In summary, this part-task training strategy allows extensive practice on error detection and correction of the most difficult and critical component of the carrier-landing task,

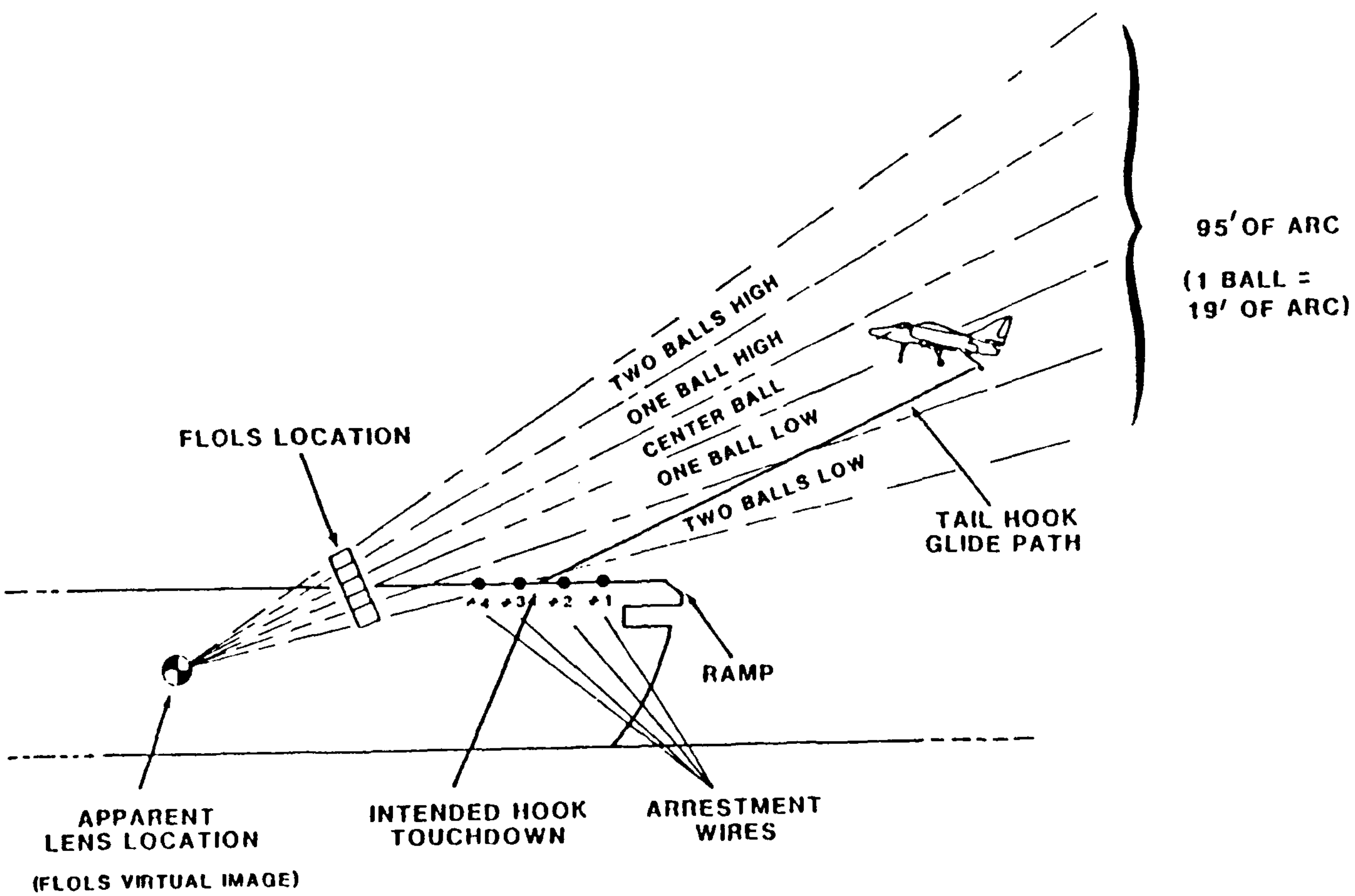


Figure 1. Carrier approach schematic depicting FLOLS envelope, tail hook glide path, and arrestment wire locations.

glideslope control. Secondly, the strategy provides knowledge of component interaction which apparently is necessary for a task with interdependent components. The point on the glideslope that was chosen for the part training resulted in a task of moderate difficulty, and was a point in a normal approach at which fine control responses start to become critical.

FLOLS TYPE

Primary glideslope displacement information for a carrier approach is provided by the Fresnel Lens Optical Landing System (FLOLS). It consists of light sources behind five vertically stacked Fresnel lenses that are situated between two horizontal light arrays known as datum bars. The array of lenses and lamps provide a virtual image which appears to the pilot as a single light located 150 feet behind the datum bars. This light, known as the meatball, is visible to the pilot through the center lens when he is within 9.5 minutes of arc of the glideslope and is seen as level with the datum bars. As the aircraft moves more than 9.5 minutes of arc above or below the glideslope, the meatball is seen through higher or lower Fresnel lenses to give the appearance of a light moving vertically above or below the line of the datum bars (Figure 1).

Although the FLOLS provides the primary displacement information for glideslope control, it has long been recognized that the system is less than optimum (Brictson, 1967; Perry, 1968). Because the information from the meatball is of zero-order (displacement only), there are substantial lags between incorrect control inputs and the subsequent error information from the FLOLS. That is, a rate (first-order) error must exist for some short period of time before it produces a perceptible displacement (zero-order) error (Kaul, Collyer, and Lintern, 1980).

One technique to compensate for the lags between control inputs and subsequent error information would be to add a first-order component to the zero-order component that is indicated by the meatball. However, this is less than desirable since the pilot would no longer have unambiguous information about his position above or below the glideslope. Kaul et al. (1980) overcame this problem by adding another element to the FLOLS display. Vertical light arrays appearing as bars extending up or down from the inside of the datum bars were added to the FLOLS to provide a first-order display with no loss of the information presently available from the meatball.

Kaul et al. tested two configurations of the vertical bars. In one, the algorithm drove the arrows up or down depending on whether the meatball was moving up or down. This was designated the RATE display. In the other, the algorithm drove the vertical bars in proportion to the difference between the actual and the ideal descent rates so that null indications from the arrows would return the pilot to, or maintain him on, the glideslope. This was designated the COMMAND display.

Results of that study showed that the approach performance with the COMMAND display was more stable and accurate than with the CONVENTIONAL display. Root mean square (RMS) glideslope error scores (standard scores used to measure performance on a tracking task) for the COMMAND display were 40% to 50% better than those for the CONVENTIONAL display. Performance with the RATE display tended to lie between performance with the CONVENTIONAL and COMMAND displays (Kaul et al., 1980). The considerable performance enhancement induced by these first-order displays suggest their potential as a training aid. Weller (1979) has argued that first-order displays might teach approach glideslope control techniques for carrier landing and these first-order displays might even help students learn to use a conventional FLOLS display more effectively.

Although Westra (1982) found no differential transfer advantage following instruction with the COMMAND display, the substantial performance advantages shown by Kaul et al. prompted a further test. Westra had chosen the COMMAND display for his training experiment because it had induced the more powerful performance effects in the early experiment by Kaul et al. However, it is also apparent that the COMMAND display permits students to fly the glideslope accurately without attending to the conventional displacement information. A dependency on the command information may develop that would disrupt performance on transfer to the CONVENTIONAL display. On the other hand, the RATE display does not permit total neglect of the conventional displacement information. Thus, disruptive dependencies are less likely to develop. The possibility that the RATE display is a better choice for training systems is also supported by Pew (1966) who showed a performance advantage in transfer from a rate tracking display to a displacement tracking system. As the theory and knowledge surrounding the use of the first-order displays for both performance and learning is meager, both were examined in this experiment.

FLOLS SIZE

In the real environment, the FLOLS display is generated by incandescent lights. In a flight simulator, it is more convenient and less expensive to generate a FLOLS image by computer. Because the FLOLS is relatively small and must be perceived accurately, a high-fidelity visual simulator is required to represent it at its true relative size. Alternatively, the FLOLS might be represented as larger than its normal size. The issue of whether the size of a simulated FLOLS needs to correspond to its size in the real environment remains unresolved. From an engineering perspective, a large FLOLS would be advantageous because to simulate the FLOLS display accurately would require a high-detail and costly visual system.

From a training perspective, a large FLOLS may or may not be advantageous. An oversize FLOLS might also be regarded as an augmenting cue and may help the student make better sense at what he is seeing when flying the simulator (Hennessy et al., 1981) as did the augmented feedback used by Lintern (1980) to teach landings in a light aircraft. Thus, FLOLS size was included in the experiment to examine its relative effectiveness for simulator training.

In summary, this experiment was conducted to investigate methods of improving simulator training effectiveness of the carrier landing task. A segmentation method of part-task training vs whole-task training and two visual factors, FLOLS type and FLOLS size, were investigated at the Visual Technology Research Simulator. FLOLS type consisted of the conventional FLOLS display and two first-order displays, RATE and COMMAND. FLOLS size consisted of small and large simulated FLOLS.

SECTION II

METHOD

APPARATUS

The Visual Technology Research Simulator (VTRS), described elsewhere by Collyer and Chambers (1978), consists of a fully instrumented T-2C Navy jet trainer cockpit, a six degree-of-freedom synergistic motion platform, a 32-element G-seat, a wide-angle visual system that can project computer-generated color images, and an Experimenter/Operator Control Station. The motion system and G-seat were not used in this experiment.

The T-2C is the Navy's primary jet trainer. It is a twin turbojet, subsonic aircraft. All major T2-C controls and displays are simulated in the VTRS. Carrier arrested landing and catapult takeoff capabilities are also provided.

The visual display is a full-color wide-angle real image presented on a 10-foot radius spherical screen. The entire display system, consisting of the screen and two projectors, is mounted on the motion base.

The experimenter/operator station provides the capability of interacting with the computer and flight simulator for the purpose of developing, controlling, and monitoring the experiment.

VISUAL SYSTEM. The background subtended 50 degrees above to 30 degrees below the pilot's eye level and 80 degrees to either side of the cockpit. The carrier image, a daytime representation of the USS Forrestal (CVA 59), was generated by computer and projected onto the background through a 1025-line video system. The FLOLS and carrier wake were also generated by this method (Figure 2).

Average delay between control inputs and generation of the corresponding visual scene was approximately 117 msec. Calculation of new aircraft coordinates required 50 msec, while calculation of the coordinates for the visual scene corresponding to the viewpoint from the new aircraft coordinates required 17 msec. An updated visual scene was displayed every 33 msec.

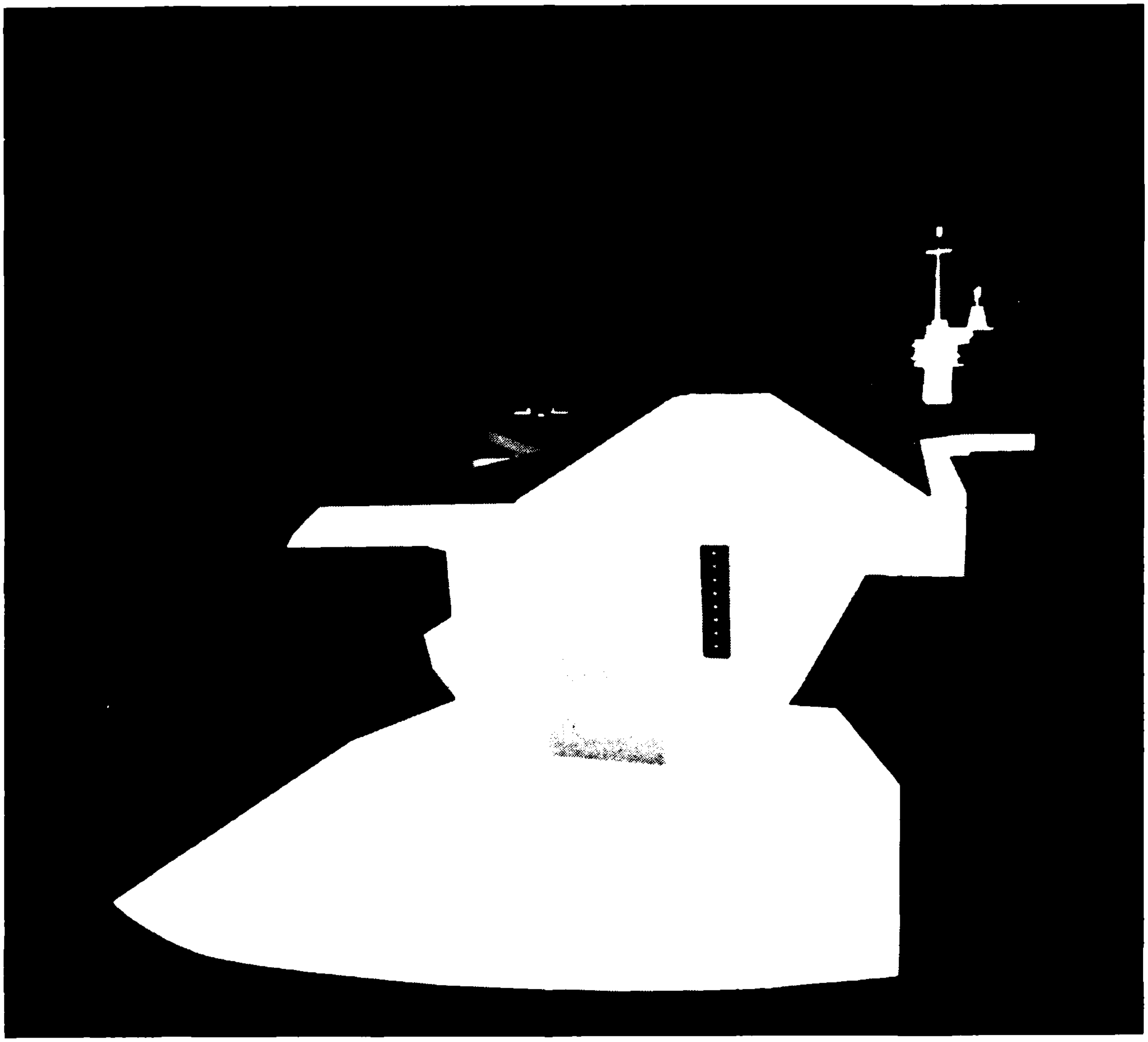


Figure 2. Computer-generated image of the day carrier with FLOLS and portion of wake.

The sky was light blue and brightness was approximately .12 foot-Lambert (fL). The seascape was dark blue and brightness was approximately .45 fL. The brightest area of the carrier was approximately 2.6 fL. Except for the horizon, there were no features represented in either the sky or sea.

The configuration of the FLOLS is shown in Figure 3. The FLOLS was centered 414 feet down the landing deck and 61 feet to the left of the centerline. It was set at a nominal 3.5 degree glideslope and with a lateral viewing wedge of 52 degrees.

EXPERIMENT

Three training factors--task configuration (part vs whole), FLOLS type, and FLOLS size--were investigated as possible training aids for the carrier landing task. After 30 trials on one of the training conditions, subjects were transferred for another 30 trials to the criterion configuration. Performances in the transfer phase were used to assess the differential effects of the training conditions.

TASK CONFIGURATION. For the whole-task condition, the simulator was initialized with the aircraft at 9000 feet from the ramp, on glideslope and centerline, and in the approach configuration (hook and wheels down, speed brake out, 15 units Angle of Attack (AOA), half flaps, and power at 83%). A trial was flown from the initial condition to wire arrestment or, in the case of a bolter, to 1000 feet past the carrier. The carrier was set on a heading of 360 degrees at 20 knots. Environmental wind was set to produce a relative wind component of 25 knots down the deck with no effective crosswind.

For the part-task condition, the simulator was initialized with the aircraft at 1800 feet from the ramp, on glideslope and centerline, and in the approach configuration (hook and wheels down, speed brake out, 15 units AOA, and half flaps). Power was set at 85% with vertical velocity set at approximately zero feet/minute. Ground position was frozen so that the simulated aircraft could not converge on the carrier nor deviate from lineup. All other control responses were the same as for the whole-task condition. A trial was flown for 60 seconds after release from the initial condition. Sixty seconds of practice in the part-task condition corresponded approximately to the amount of time required to fly a whole approach (9000 feet to the ramp). The carrier was set on a heading of 360 degrees at 0 knots with no environmental wind to produce relative wind conditions similar to those of the whole task.

FLOLS TYPE. There were three levels of this factor. The conventional version of the FLOLS was one and the other two involved the use of vertical bars added to the conventional

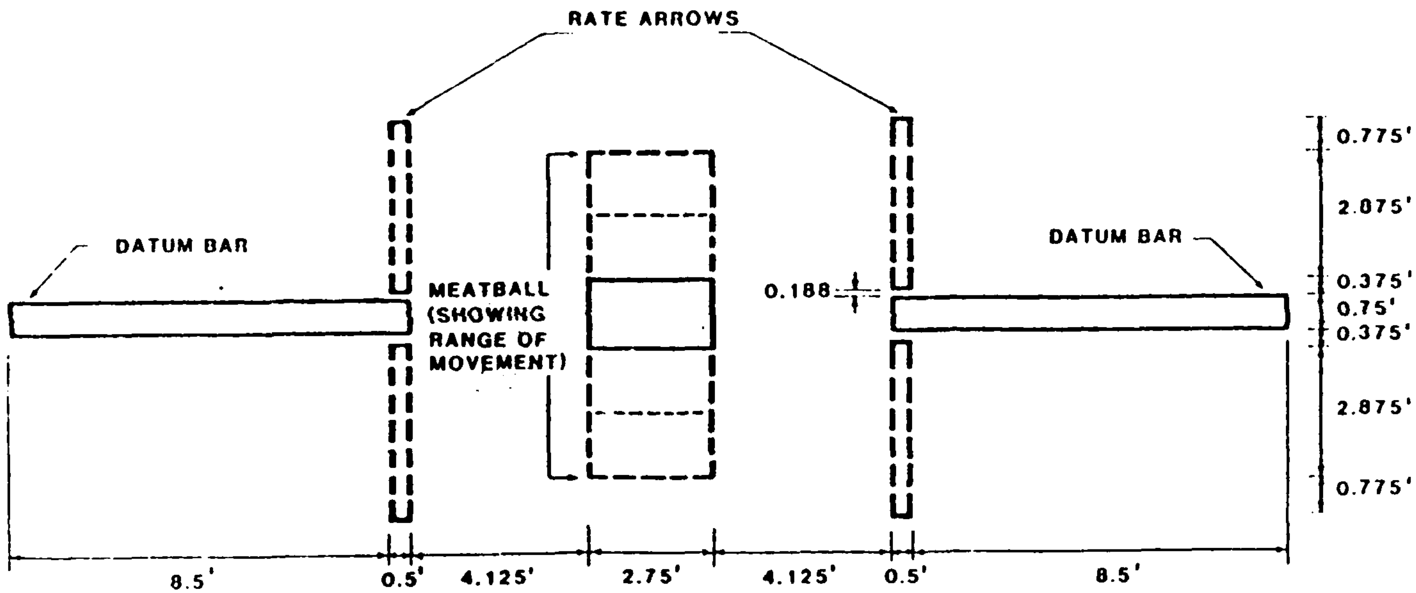


Figure 3. Configuation of FLOLS simulation showing datum bars, rate arrows, and meatball (dimensions shown are in feet).

FLOLS (Figure 3). The vertical bars provided glideslope rate of displacement information to the subjects. The two levels were designated RATE and COMMAND.

For the RATE display, the algorithm (Kaul et al., 1980) drove the arrows in proportion to the difference between actual descent rate and the descent rate that would maintain present glideslope angle with respect to the FLOLS (Figure 4).

For the COMMAND display, the algorithm (Kaul et al., 1980) drove the arrows in proportion to the difference between the glideslope displacement rate and a commanded rate that was a function of glideslope displacement. For a given aircraft velocity, range and glideslope deviation, the command function would guide the pilot back to the glideslope at the optimum rate (Figure 4).

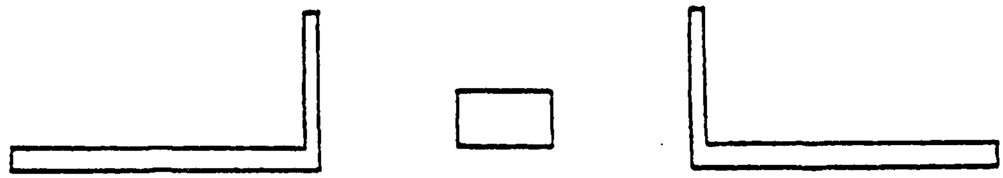
FLOLS SIZE. The FLOLS has a few critical elements that are relatively small. When represented at true scale in the VTRS, some of the elements were so small that the line-raster projection system caused them to flicker excessively as they crossed raster lines. The flicker can be avoided by making the FLOLS larger than it should be. One goal of this experiment was to assess whether a size differential in the FLOLS would affect acquisition of the task.

Even the smallest possible representation of the FLOLS had to be larger than true scale but it would be represented closer to true scale as the simulated aircraft neared the ramp. A shrinking algorithm was used to reduce the size of the simulated FLOLS during the approach. Two different shrinking algorithms were used to establish the FLOLS size factor. The small FLOLS was enlarged by a factor of 2.0 times its normal size when the distance behind the ramp was greater than 1000 feet. From 1000 feet, the size of the FLOLS was linearly reduced until it attained 1.5 times its normal size at 750 feet. It remained this size throughout the remainder of the approach. The large FLOLS was enlarged by a factor of 4.5 its normal size when the distance behind the ramp was greater than 2250 feet. From 2250 feet the size of the FLOLS was linearly reduced until it attained 1.5 times its normal size at 750 feet. It remained this size throughout the remainder of the approach. At 1800 feet from the ramp (the part-task training position), the large FLOLS was enlarged by a factor of 3.6.

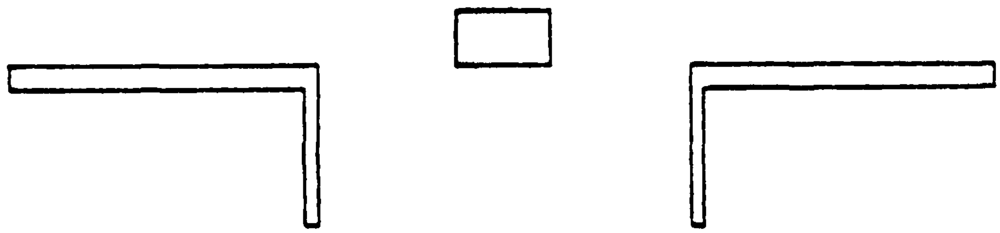
SUBJECTS

Thirty-six male college students between the age of 18 and 28 participated in the experiment at the Naval Training Equipment Center (NTEC). All subjects were paid volunteers with no flight experience.

(a) A static CONVENTIONAL display does not permit a trend interpretation. For the RATE display this figure indicates that the one-ball high condition will be maintained, while for the COMMAND display that the pilot is returning to the reference glideslope at an appropriate rate.



(b) For the RATE display this figure indicates one-ball high and going higher in relation to the reference glideslope. For the COMMAND display it indicates that the aircraft is high, and is not returning to the glideslope quickly enough (and may even be going higher).



(c) For the RATE display this figure indicates that the pilot is returning to the glideslope, while for the COMMAND display that he is returning to it too quickly and will probably fly through it.

Figure 4. Three representations of possible RATE or COMMAND displays. Figure 4(a) can also represent a CONVENTIONAL display.

EXPERIMENTAL DESIGN

A 2x2x3 full factorial quasi-transfer of training design was used in the experiment. Subjects were randomly assigned to one of the training conditions of the basic design. After training all subjects were then tested on the condition that most closely represented the carrier-landing task; that is, the 9000 feet whole-task approach with the CONVENTIONAL display and small FLOLS (Table 1).

TABLE 1. TRAINING CONDITIONS

		Conventional	Rate	Command
Whole Task	Small FLOLS	111*	112	113
	Large FLOLS	121	122	123
Part Task	Small FLOLS	211	212	213
	Large FLOLS	221	222	223

Condition Codes:

Whole Task	= 1	Part Task	= 2		
Small FLOLS	= 1	Large FLOLS	= 2		
Conventional	= 1	Rate	= 2	Command	= 3

* Also used in the transfer configuration for all groups.

PROCEDURES

Subjects were given a 1.5-hour briefing on carrier-landing procedures. Their simulator sequence consisted of 30 training trials and 30 transfer trials over a two-day period. No familiarization flights were permitted. Instructional feedback on their performance was given by the experimenter after each training trial. Feedback for lateral control was given on the first three transfer trials. There was no instructional feedback on the remaining transfer trials.

BRIEFING. The briefing materials consisted of information on carrier-landing procedures for each subject, and information on their specific training condition. A complete set of briefing material can be obtained from the VTRS facility. Subjects read the briefing materials and were then instructed on carrier-landing procedures. The experimenter also described the location of cockpit instruments and controls.

INSTRUCTIONAL FEEDBACK. Normally, the Landing Signal Officer (LSO) provides feedback to the pilot during an approach. However, the services an LSO could not be secured for this experiment. While this might initially appear unfortunate, it has been difficult in previous research to ensure that LSOs or instructors treat all subjects similarly. A tendency to offer more support based on the way the student performs has been noted. In this experiment, where student performances should depend to some extent on their training condition (Lintern et al., 1981), any tendency to give extra assistance to poor performances could confound the results of the experiment.

In an attempt to maintain experimental control of student/instructor interactions, personnel with a psychological background were trained to teach the required skills. While this approach may lose something in the quality of instruction, that loss would seem to be offset by gains in experimental control. This approach appeared to have worked successfully in a previous carrier-landing experiment where the experimenter provided feedback to Navy and Air Force pilots after each approach (Lintern et al., 1981).

The experimenter gave instructional feedback after every training trial. To aid in the instructional feedback, a graphic display provided plots of glideslope deviation, angle-of-attack deviation, lineup deviation, vertical velocity, aircraft pitch, and power setting. Plots were provided for the final 6000 feet of the whole-task condition and the entire 60 seconds of the part-task condition. Feedback was limited to major problems or errors that occurred during the trial.

COVARIATE TASK. In simulation research, individual differences tend to account for much of the unexplained variance (Westra, 1981). One method of reducing the unexplained variance is to assess subject aptitude for the task and account for some of the between-subject variance through an analysis of covariance. An ATARI video game was selected as a covariate since prior research had shown a high test-retest reliability and other characteristics desirable in a covariate (Jones, Kennedy and Bittner, 1981). Furthermore, the ATARI video game is a compensatory tracking task as in the carrier-landing task (Lintern and Kennedy, 1982).

Subjects were tested with the ATARI Air Combat Maneuvering (ACM) game (Cartridge CX2601, game No. 24, difficulty 'b', right controller) prior to their flight in the simulator. All subjects completed a total of 30 games. A subject's score for one game is the total number of hits during a 2.25-minute trial.

PERFORMANCE MEASUREMENT AND DATA ANALYSIS

Parameters of aircraft position were sampled at 30 Hz and used to derive summary scores from the desired approach path for the following segments.

Segment	Whole Task	Park Task
Start	6000 ft to 4500 ft	21 sec to 30 sec
Far-Middle	4500 ft to 3000 ft	31 sec to 40 sec
Middle	3000 ft to 1500 ft	41 sec to 50 sec
Close-In	1500 ft to Ramp	51 sec to 60 sec

Root-Mean Square (RMS) error scores were calculated for glideslope, lineup and angle of attack. Mean algebraic error scores were also calculated for glideslope.

Repeated measures analyses of covariance were the primary statistical tests of the data. Orthogonal comparison of main effects of Trials 1-5 vs 26-30, 6-10 vs 21-25 and 11-15 vs 16-20 were computed to assess interactions of effects with trials. This analysis gives similar information to the main effects X trial block interactions of the main ANOVA, but provides a more powerful test of initial and brief effects at time of transfer. It was considered advisable to undertake this test and set statistical significance at the 0.10 level in view of the limited power allowed by the small number of subjects available for this experiment. The power analysis showing the probability of detecting a large, medium, or small effect of RMS glideslope error for the middle (3000 ft to 1500 ft) and close-in (1500 ft to ramp) segments are presented in Appendix A. The data was also blocked (5-trial means) to increase trial-to-trial reliability. Eta squared was calculated to estimate the proportion of variance accounted for by significant effects.

SECTION III

RESULTS

Statistical analyses were conducted on both the training and transfer data. The training data were analyzed to check the effectiveness of the factor manipulations and to show that learning occurred. The transfer data were analyzed to show the effects of the training manipulations on performance of the criterion task.

Data analyses are presented on Root Mean Square (RMS) and average glideslope error, RMS Angle-of-Attack (AOA) error and RMS lineup error for the middle (3000 ft to 1500 ft) and close-in (1500 ft to ramp) segments of the approach. The middle segment was selected for analysis because it contained the position at which the part-task subjects were trained. In addition, it was the last segment to maintain a substantial task difference for the FLOLS-size factor. There was no task difference as a result of this factor in the final 1000 feet of the approach. The final segment was considered for analysis because it is the most critical segment of the task.

Preliminary analysis of the data to check for normality, symmetry and homogeneity of variances showed the RMS error scores to be highly skewed with unequal variances. Thus, RMS error scores were log (X+1) transformed prior to analysis of variance to satisfy the assumptions of normality and homogeneity of variance. Although transformation to correct for violation of these assumptions is often considered unnecessary, the failure to do so can result in a loss of statistical power (Levine and Dunlap, 1982). As there was no apparent disadvantage resulting from the transformation, and there were specific theoretical advantages, the log transform was applied routinely to all RMS scores. For descriptive purposes, means of nontransformed scores are presented in tables and graphs.

The proportion of variance (eta squared) accounted for by significant effects is also discussed. Following Cohen (1977), values for eta squared of 14% are considered to represent large effects, 6% to represent medium effects, and 1% to represent small effects.

TRAINING DATA

Trends in training data, although informative, are not central to training issues. The best use of training data are to check for learning trends and to validate factor manipulations. Significant effects are summarized in Table 2. Means and repeated measures' analysis of covariance summaries

TABLE 2. SUMMARY OF SIGNIFICANT TRAINING EFFECTS

	RMS Glideslope Error		Average Glideslope Error		RMS Angle of Attack Error	
	Middle	Close-In	Middle	Close-In	Middle	Close-In
Task (Ta)					**	***
FLOLS Size (FS)						
FLOLS Type (FT)						
Ta X FS	*	*	**	**		
Ta X FT						
FS X FT						
Ta X FS X FT						
Covariate						
Blocks (B)	***	***	***	***	***	***
B X Ta					*	
B X FS						
B X FT						
B X Ta X FS	***		*	**		
B X Ta X FT						
B X FS X FT	***				***	**
B X Ta X FS X FT						

*: $p < .10$
**: $p < .05$
***: $p < .01$

are presented in Tables B-1 to B-12 in Appendix B. No training data are presented on RMS lineup error since the part-task subjects could not deviate from lineup.

Significant learning effects were apparent for the three dependent measures that are analyzed (Table 2). They accounted for an average of 31% of the within-subjects experimental variance (Tables B-1 to B-6). RMS AOA error was significantly higher with the whole task than with the part task (Table 2). There were no other significant main effects.

The task by FLOLS size interaction was significant for RMS and average glideslope error. These interactions are shown in Figures 5 and 6. The large FLOLS reduced RMS glideslope error with the whole task but increased them with the part task. The opposite was true with the small FLOLS. Average glideslope error indicated that approaches tended to be higher with the conditions showing highest RMS glideslope error.

Two interactions with trial blocks also appear to be noteworthy. The block by task by FLOLS size interaction for RMS glideslope error is diagrammed in Figure 7. This interaction appeared to be due to the differences in error scores in the first 10 trials. The error scores were higher for the whole task with the small FLOLS and for the part task with large FLOLS. Similar trends were found with average glideslope error.

The blocks by FLOLS size by FLOLS type interaction was also significant for the RMS glideslope error in the middle segment, and for RMS AOA error in both segments. Higher error scores were apparent in early trials with the large FLOLS and the rate display. Higher error scores for RMS AOA were also apparent in early trials with the small FLOLS and the command display.

TRANSFER DATA

The transfer trials consisted of the experimental training condition most representative of the operational carrier-landing task (9000 ft straight-in approach, conventional and small FLOLS). Significant transfer effects are summarized in Table 3. Means and repeated measures analysis of covariance summaries are in Tables C-1 to C-16 in Appendix C.

GLIDESLOPE ERROR. With only minor exceptions, RMS and average glideslope error effects showed similar trends (Table 3). The only significant main effect was that of task type. RMS glideslope error scores were higher following part-task training. Average error scores indicated a tendency for all subjects to fly above the glideslope, but the part-trained subjects flew significantly higher than did the whole-trained subjects. These effects accounted for an average of 14% of the between-subjects experimental variance.

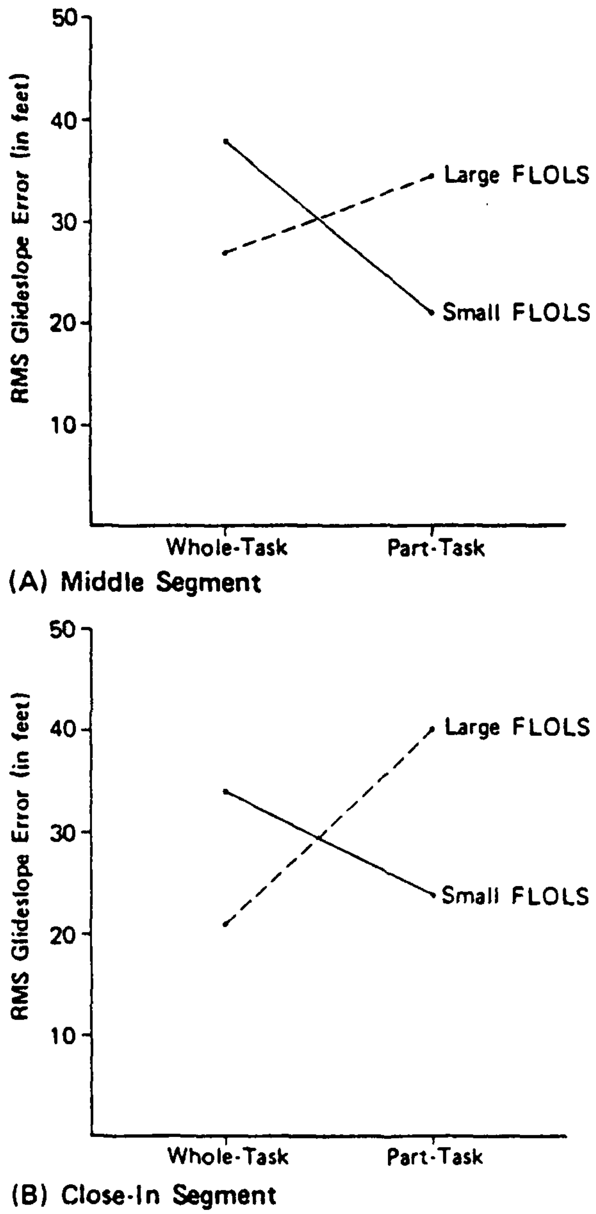


Figure 5. Task x FLOLS size interactions for RMS glideslope error during training.

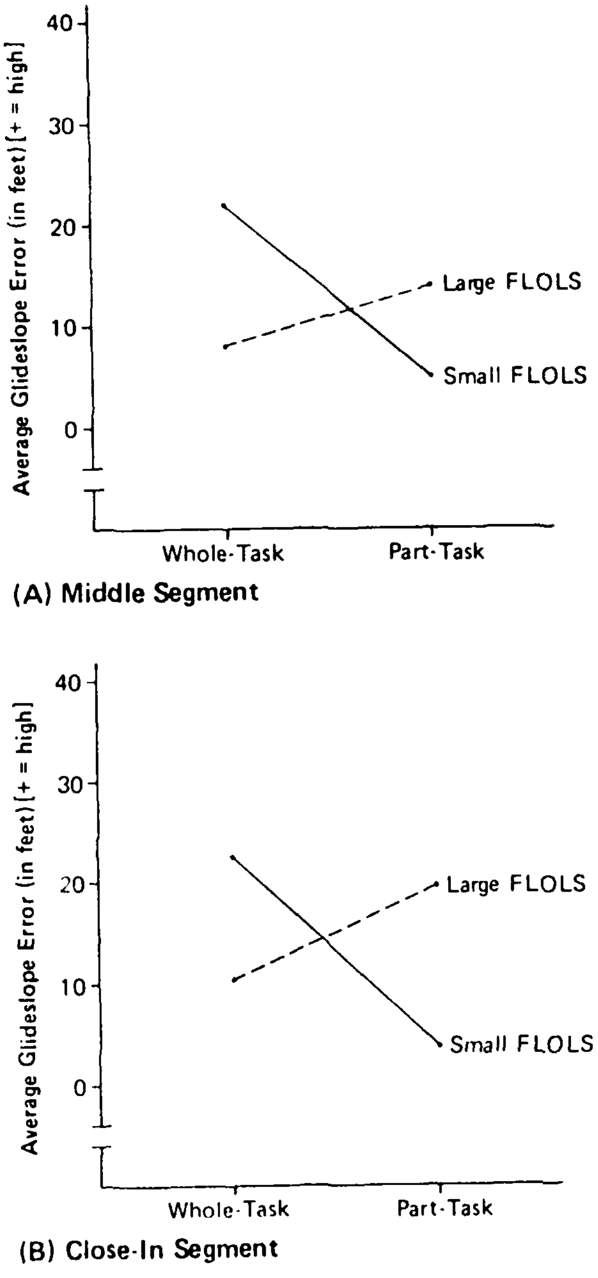


Figure 6. Task x FLOLS size interactions for average glideslope error during training.

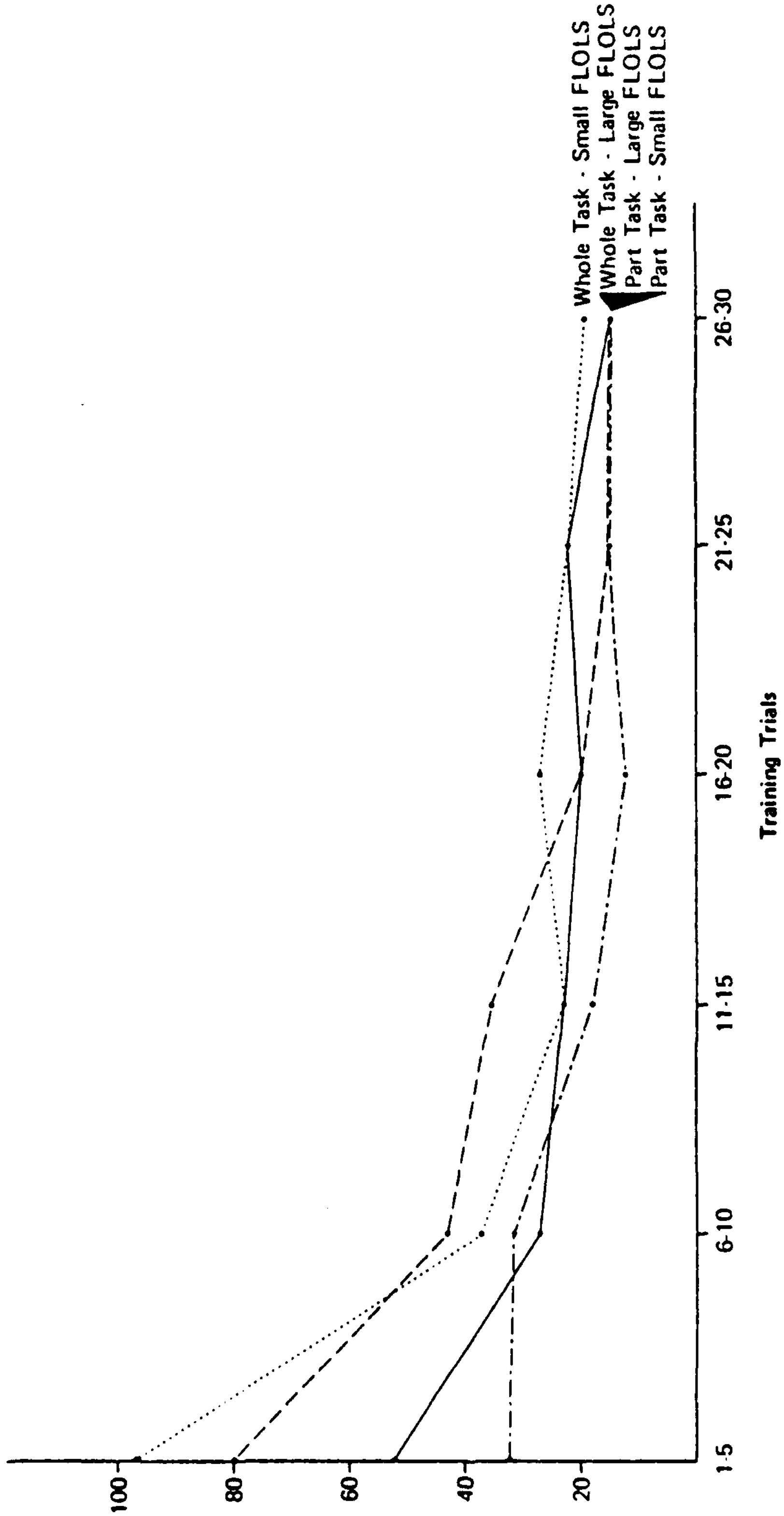


Figure 7. Block x task x FLOLS size interaction of RMS glideslope error for the middle segment during training.

TABLE 3. SUMMARY OF SIGNIFICANT TRANSFER EFFECTS

	RMS Glideslope Error		Average Glideslope Error	
	Middle	Close-In	Middle	Close-In
Task (TA)	**	**	***	*
FLOLS Size (FS)				
FLOLS Type (FT)				
Ta X FS				
Ta X FT				
FS X FT				
Ta X FS X FT		**		
Covariate		***		
Blocks (B)	***	***	***	***
B X Ta	**	***	***	***
B X FS				
B X FT				
B X Ta X FS				
B X Ta X FT	*			
B X FS X FT				
B X Ta X FS X FT				

	RMS AOA Error		RMS Lineup Error	
	Middle	Close-In	Middle	Close-In
Task (Ta)				
FLOLS Size (FS)				
FLOLS Type (FT)			*	
Ta X FS				
Ta X FT				
FS X FT			**	*
Ta X FS X FT		*		
Covariate		*	***	***
Blocks (B)	***	*		***
B X Ta	*			*
B X FS				
B X FT	**			**
B X Ta X FS	***	*	**	
B X Ta X FT				
B X FS X FT				
B X Ta X FS X FT				

*p: $< .10$
**p: $< .05$
***p: $< .01$

Significant block effects indicated that glideslope errors decreased throughout transfer. As shown by the significant block by task interactions, part trained subjects performed very poorly in early transfer, but were only slightly disadvantaged in relation to the whole-trained subjects towards the end of the transfer phase (Figures 8 and 9). These interactions accounted for an average of 9% of the within-subjects experimental variance.

There was a block by task by FLOLS type interaction in the middle segment for RMS glideslope error (Table 3). Figure 10 suggests that this interaction resulted from poor early transfer performances of part trained groups. However, subjects trained on the part task with the RATE display had the lowest error scores among part-trained subjects at the start of transfer, and these error scores remained consistently lower throughout transfer. Figure 10 also shows that subjects trained on the whole task with the CONVENTIONAL display had the lowest error scores throughout transfer.

There were various significant interactions of FLOLS type comparing trials 1-5 versus 26-30 for both RMS and average glideslope error. These interactions are summarized in Table 4. In general, a significant interaction of this type indicates that the magnitude of differences between conditions changed from early in transfer to late in transfer. An interaction effect of this type would also be indicated by a significant blocks by factor interaction in the ANOVA. However, the statistical power of the test in the ANOVA was low because of the small number of subjects available for the experiment. The procedure employed here was used because of its potential to provide a more powerful test of block by factor interactions.

Figures 11-A and 11-B show RMS glideslope error was lower for subjects trained with the COMMAND display versus those trained with the CONVENTIONAL display in trials 1-5. Later in transfer (trials 26-30), subjects trained with the CONVENTIONAL display had surpassed those trained with the COMMAND display. Figure 11-C also shows RMS glideslope error was lower for subjects trained with the RATE display versus those trained with the CONVENTIONAL display in trials 1-5, but this effect quickly dissipated.

While subjects tended to fly above the glideslope in early transfer trials, this tendency was more extreme after training with the CONVENTIONAL display than after training with the RATE display (Figure 12). The tendency for CONVENTIONAL trained subjects to fly higher on the glideslope continued through transfer trials 11-15, but not thereafter.

There was an interaction of FLOLS size for the comparison of trials 6-10 versus 21-25 in both the middle segment ($F(1,120) = 4.50$, $p < .05$) and close-in segment ($F(1,120) = 4.48$, $p < .05$)

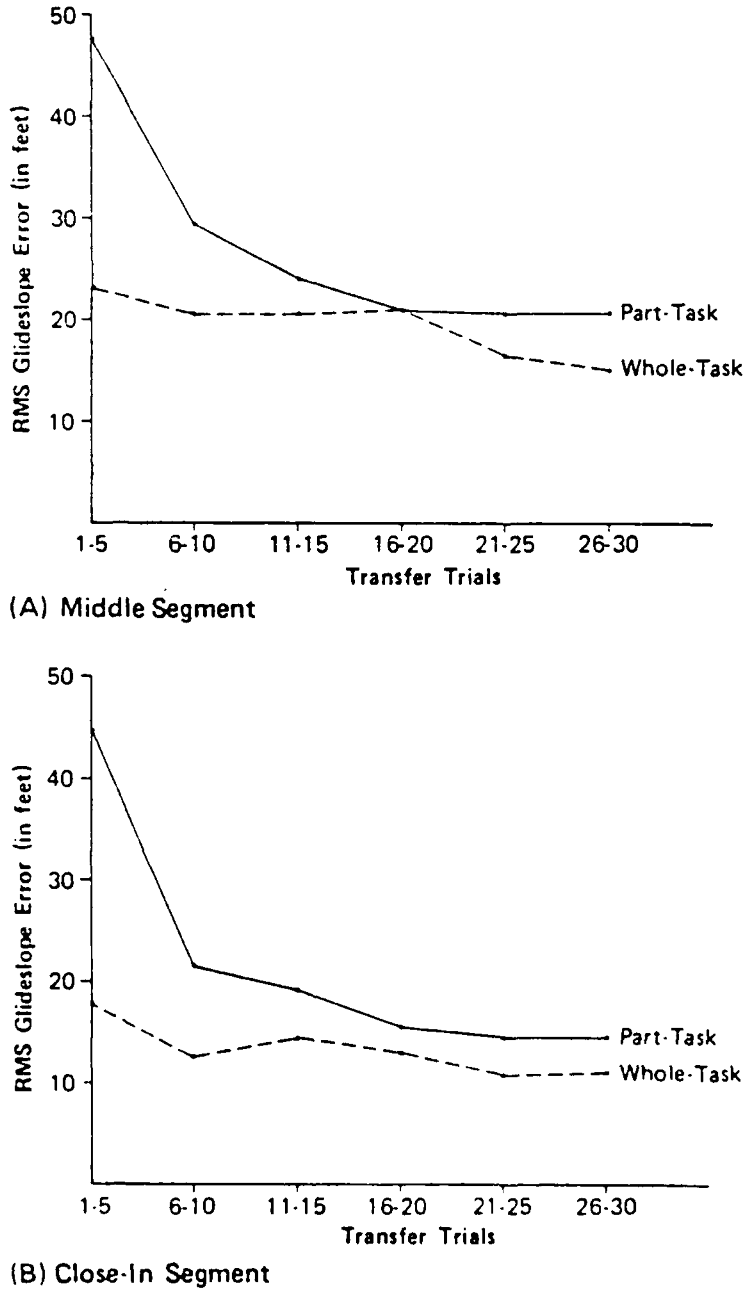
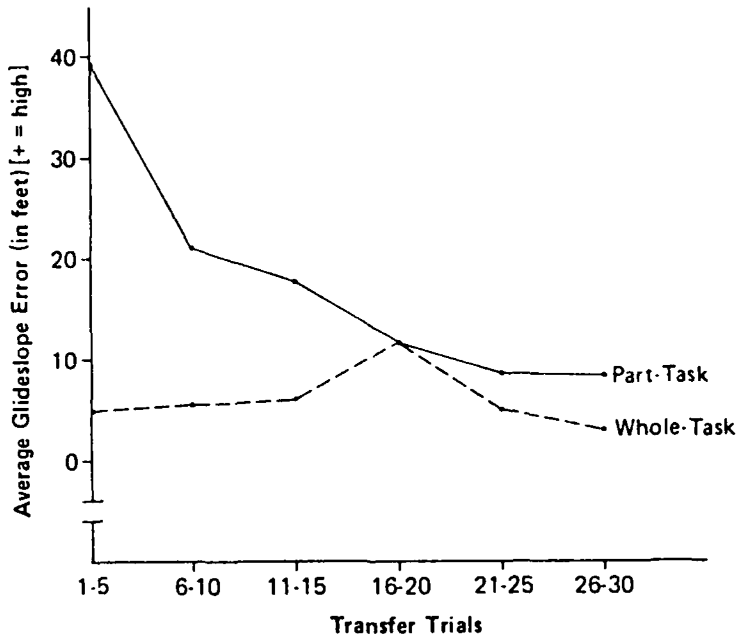
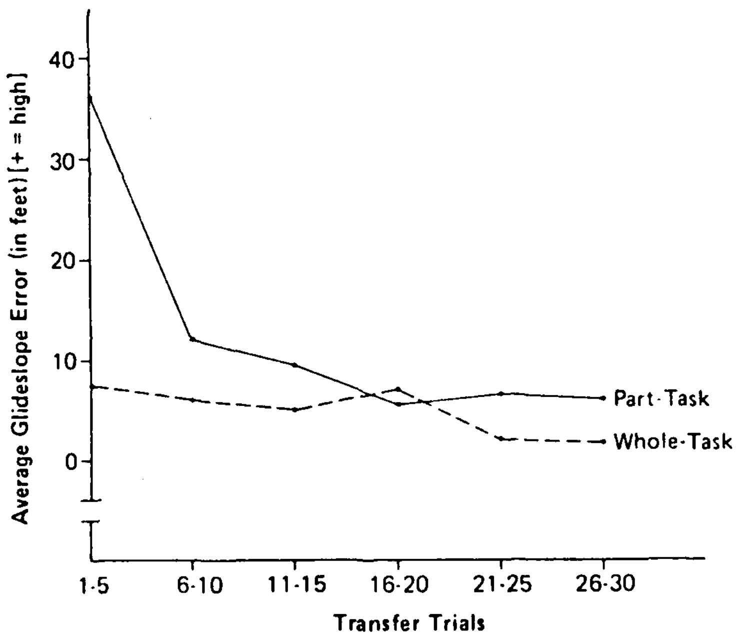


Figure 8. Block x task interactions for RMS glideslope error during transfer.



(A) Middle Segment



(B) Close-In Segment

Figure 9. Block x task interactions for average glideslope error during transfer.

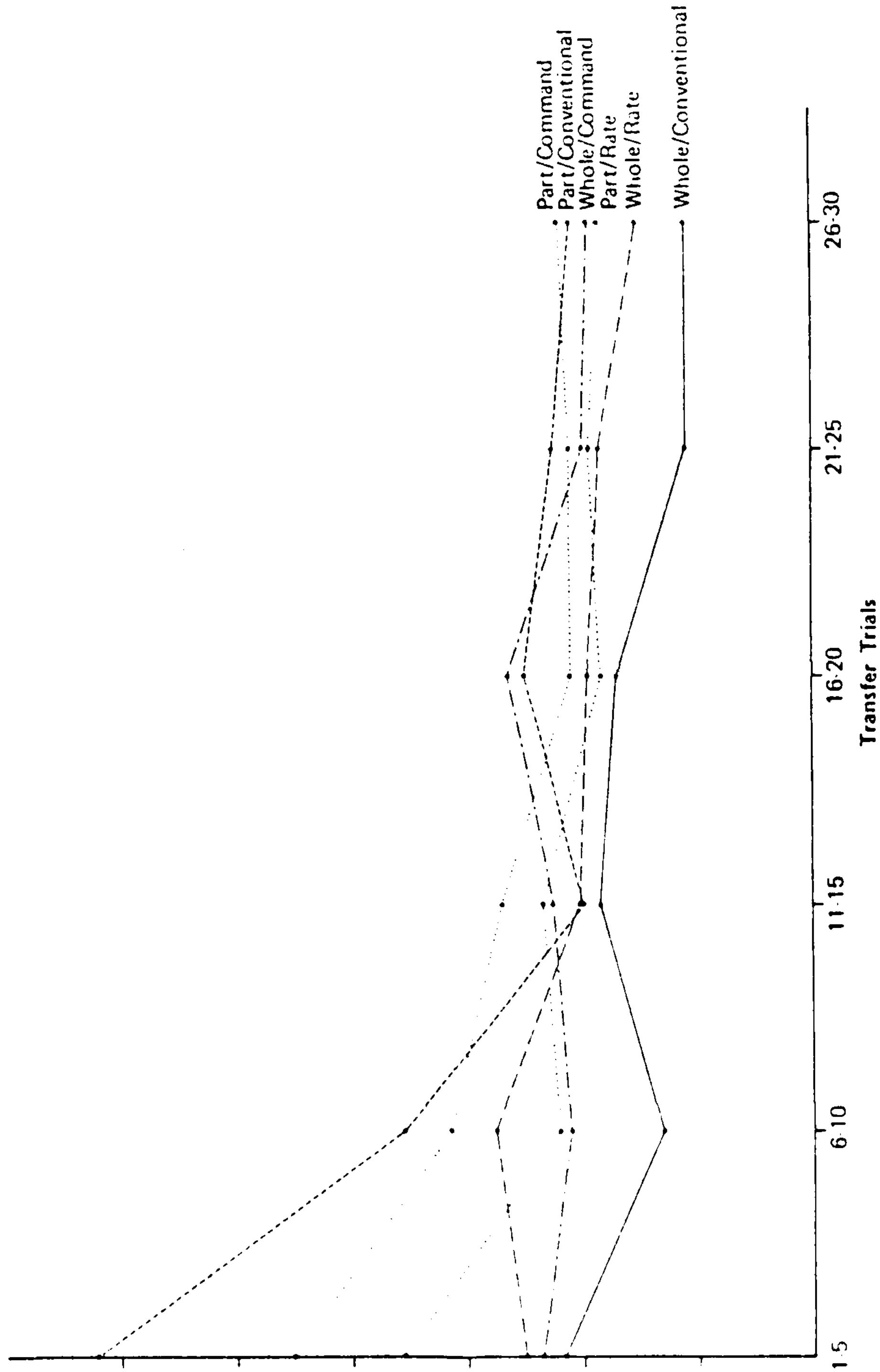


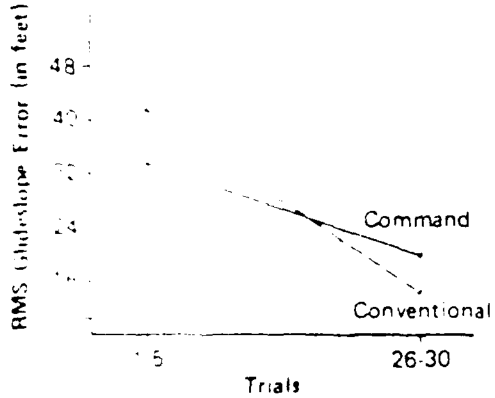
Figure 10. Block x task x FLOLS type interaction of RMS glideslope error for the middle segment during transfer.

TABLE 4. SUMMARY OF FLOLS TYPE INTERACTIONS COMPARING TRIALS 1-5 VERSUS 26-30 FOR RMS AND AVERAGE GLIDESLOPE ERROR

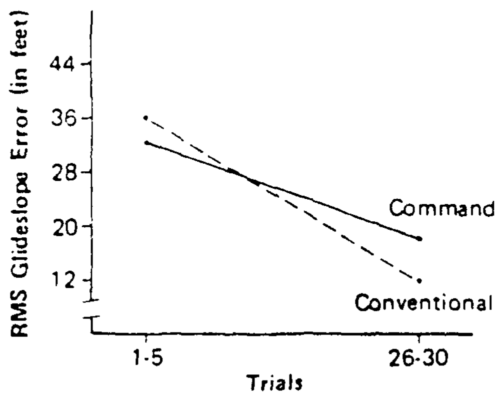
	RMS Glideslope Error		
Factor	Segment	F	Prob
Conventional vs COMMAND	Middle	3.50	*
Conventional vs COMMAND	Close-in	6.19	**
Conventional vs RATE	Close-in	2.92	*

	Average Glideslope Error		
Factor	Segment	F	Prob
Conventional vs RATE	Middle	5.42	**
Conventional vs RATE	Close-in	4.79	**

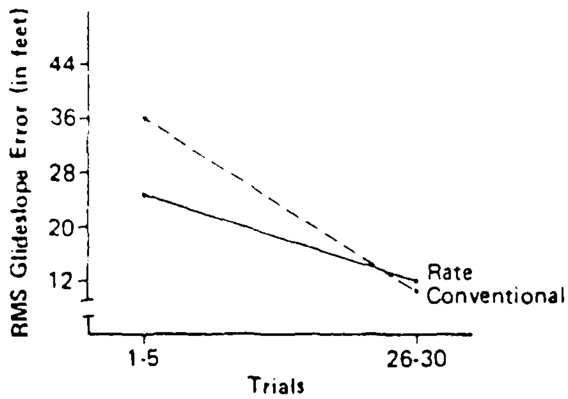
*p: < .10
**p: < .05



(A) Conventional x Command
[Middle Segment]



(B) Conventional x Command
[Close-In Segment]



(C) Conventional x Rate
[Close-In Segment]

Figure 11. FLOLS type interactions of RMS glideslope error during transfer.

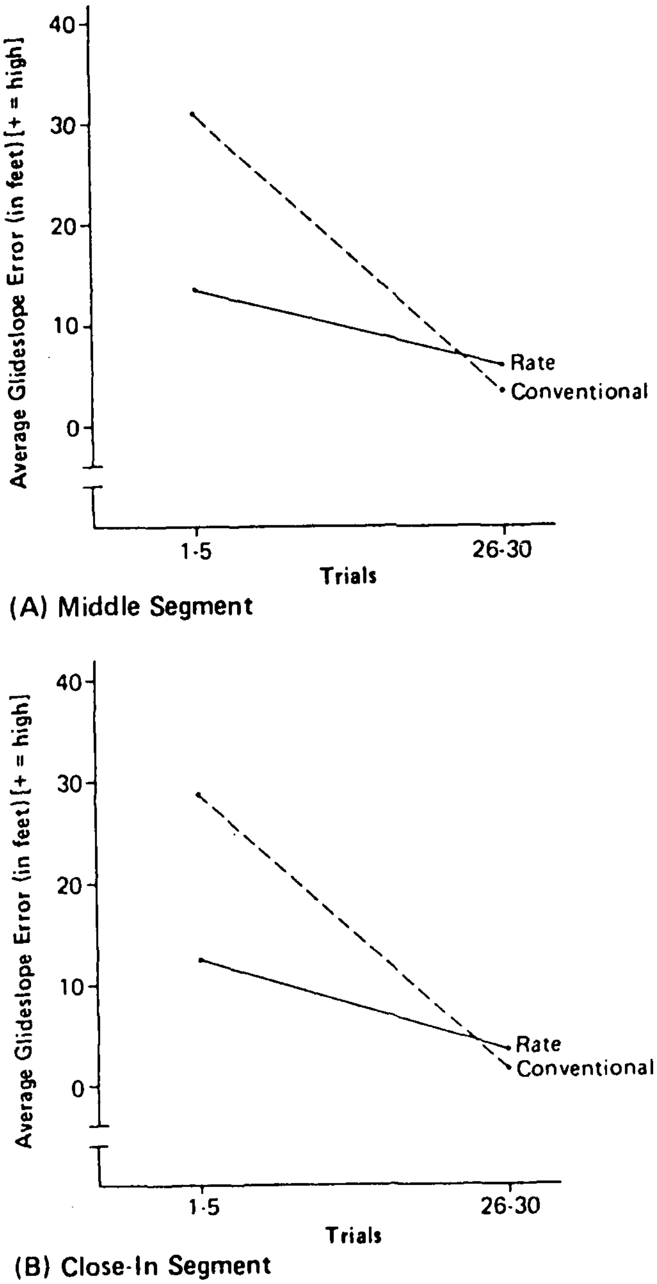


Figure 12. FLOLS type interactions for average glideslope error during transfer.

for RMS glideslope error. Error scores were lower for subjects trained with the large FLOLS versus those trained with the small FLOLS in trials 6-10. A slight reversal occurred in trials 21-25 and RMS glideslope error in this transfer block was lower for subjects trained with the small FLOLS versus those trained with the large FLOLS (Figure 13). There was no difference at the end of transfer in the critical close-in segment.

There was a significant interaction of task by FLOLS type by FLOLS size in the close-in segment for RMS glideslope error (Table 3). Transfer performance was superior for whole-task training conditions except when part-task training was combined with the RATE display and small FLOLS (Figure 14). Transfer performance following training with the part-task, RATE display, and small FLOLS condition was as good as performance under any of the whole-task conditions. This interaction accounted for 15% of the between-subjects experimental variance in the close-in segment.

The ATARI covariate was significant in the close-in segment for RMS glideslope error (Table 3). Performance on the ATARI video game accounted for a substantial 19% of the between-subjects experimental variance in this segment.

RMS ANGLE-OF-ATTACK. There were no statistically significant main effects for the transfer trials (Table 3).

There was a block by task interaction and a block by FLOLS type interaction in the middle segment (Table 3). Figure 15-A indicates that the block by task interaction was significant because of an upturn in the RMS AOA error scores for the part-trained subjects toward the end of transfer. This block by task interaction accounted for 4% of the within-subjects experimental variance in the middle segment. Figure 15-B indicates that the significant block by FLOLS type interaction resulted from a sharp improvement in RMS AOA error for the COMMAND trained subjects in early transfer, followed by a similarly sharp deterioration in later transfer. This block by FLOLS type interaction accounted for 10% of the within-subjects experimental variance in the middle segment.

There were various significant interactions comparing trials 1-5 versus 26-30 for RMS AOA error. These interactions are summarized in Table 5. RMS AOA error was lower for subjects trained on the part task versus those trained on the whole task in trials 1-5. This effect is consistent with the block by task interaction previously noted for this segment.

Figures 16-A and 16-B show RMS AOA error was lower for subjects trained with the COMMAND display versus those trained with the CONVENTIONAL display in trials 1-5. These error scores continued to be lower through transfer trials 21-25, but the trend was reversed in trials 26-30. Figures 16-C and 16-D also

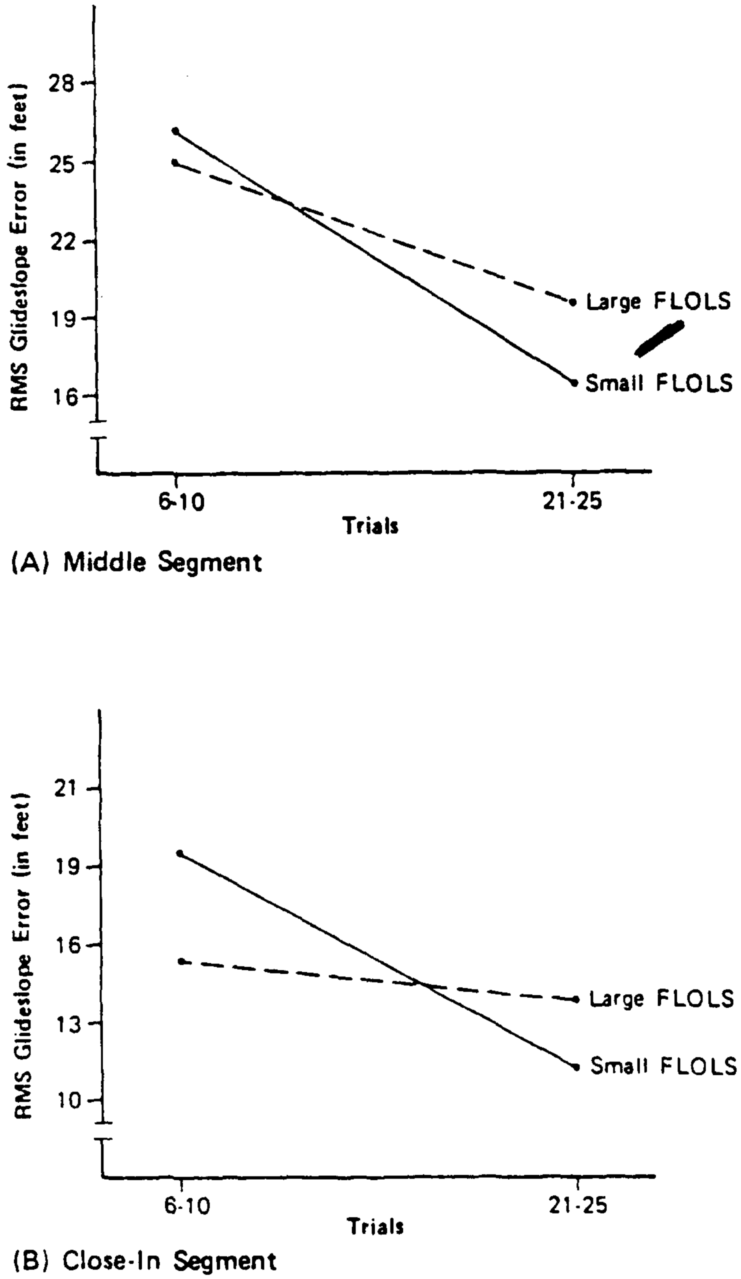


Figure 13. FLOLS size interactions of RMS glideslope error during transfer.

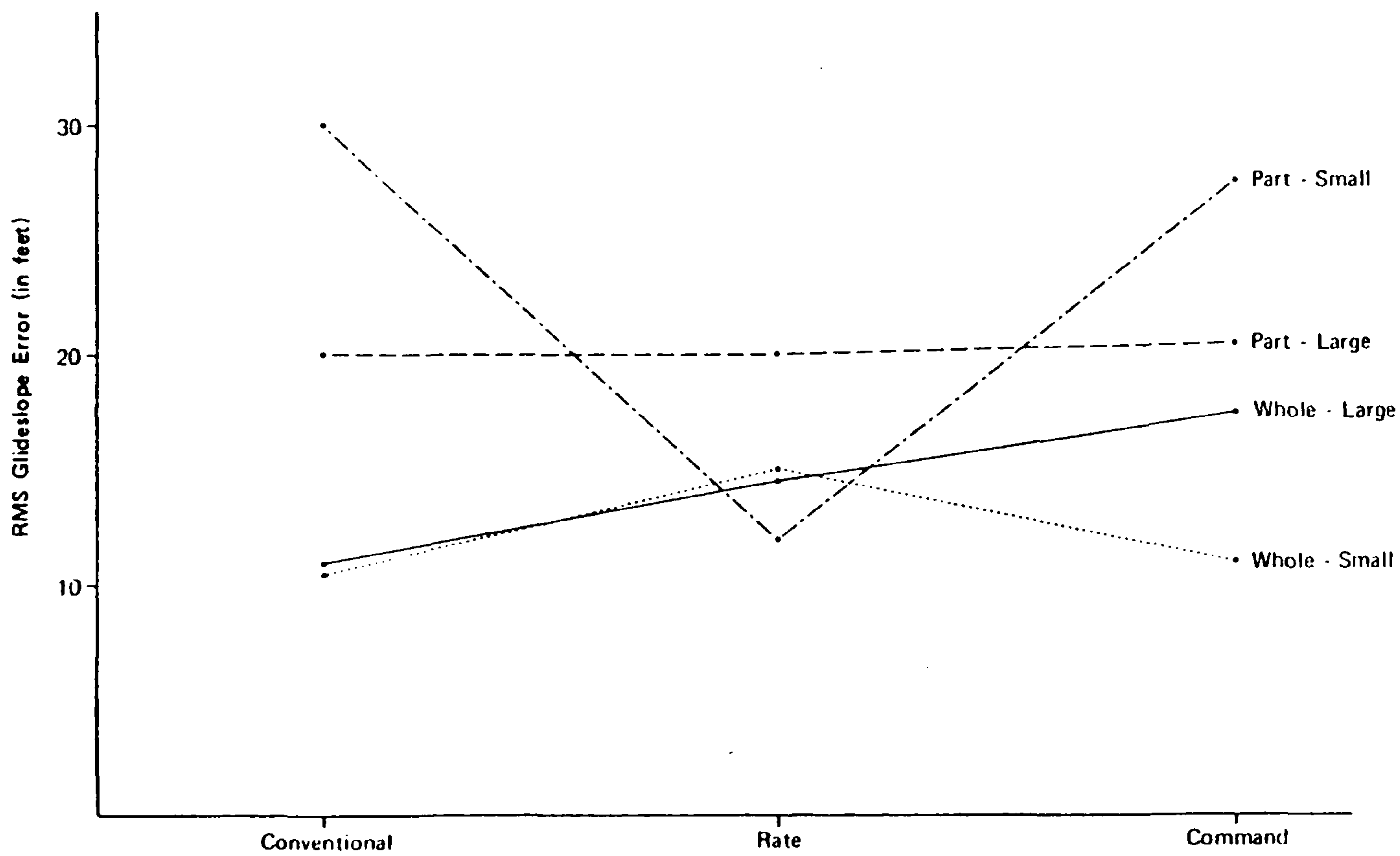
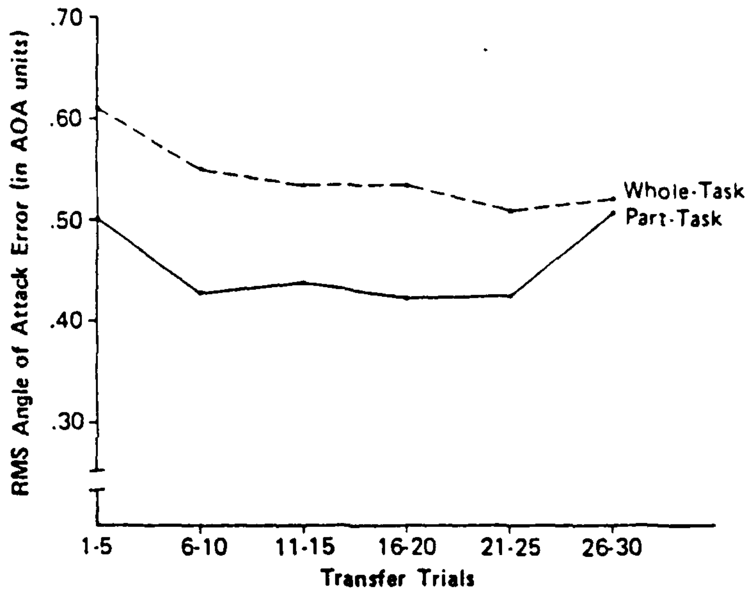
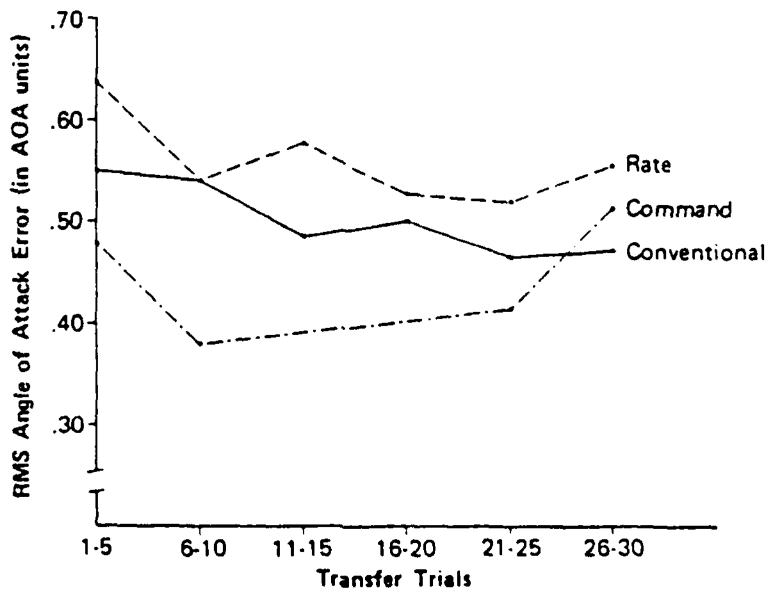


Figure 14. Task x FLOLS type x FLOLS size interaction of RMS glideslope error for the close-in segment during transfer.



(A) Block x Task



(B) Block x FLOLS Type

Figure 15. Block x task and block x FLOLS type interactions of RMS angle-of-attack error for the middle segment during transfer.

TABLE 5. SUMMARY OF TASK TYPE, FLOLS TYPE, AND FLOLS SIZE INTERACTIONS COMPARING TRIALS 1-5 VERSUS 26-30 FOR RMS AOA ERROR

		Task Type	
Factor	Segment	F	Prob
Part versus Whole	Middle	3.77	*

		FLOLS Type	
Factor	Segment	F	Prob
Conventional versus Command	Middle	5.42	**
Conventional versus Command	Close-in	3.79	*

		FLOLS Size	
Factor	Segment	F	Prob
Large versus Small	Middle	6.88	***
Large versus Small	Close-in	5.51	**

*: $p < .10$
**: $p < .05$
***: $p < .01$

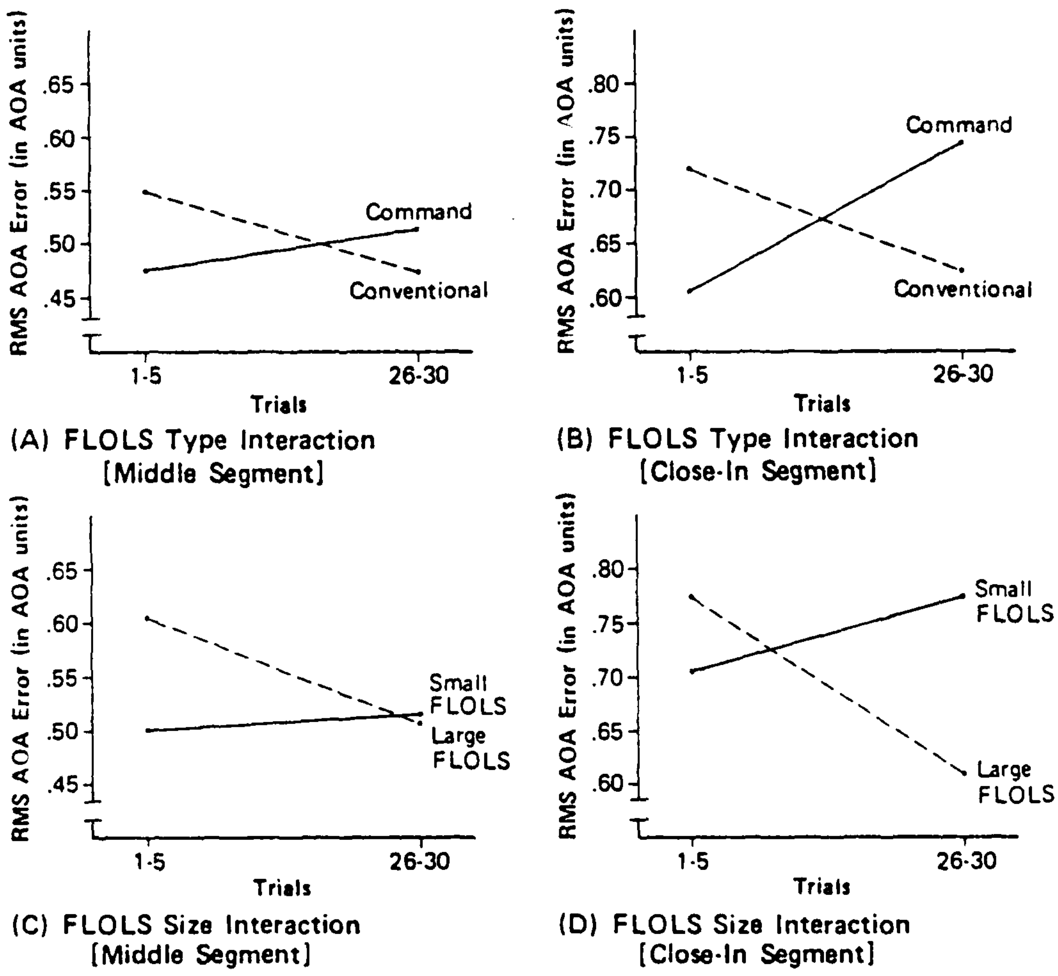


Figure 16. FLOLS type and FLOLS size interactions of RMS angle-of-attack error during transfer.

show RMS AOA error was lower for subjects trained with the small FLOLS versus those trained with the large FLOLS in trials 1-5. A reversal occurred in trials 26-30 in the close-in segment. RMS AOA error in trials 26-30 was lower for subjects trained with the large FLOLS versus those trained with the small FLOLS.

There was a block by task by FLOLS size interaction for both segments (Table 3). Figure 17 shows that in the middle segment, subjects who had trained with the whole task and large FLOLS started the transfer phase with the highest AOA error scores and that trend continued throughout transfer. Subjects who had trained with the part-task and small FLOLS started the transfer phase with the lowest error scores. However, the interaction in the critical close-in segment was only moderately significant ($p < .10$) and was not as well defined. Subjects trained with the whole task and large FLOLS had lower AOA error scores at the start of transfer versus those trained with the whole task and small FLOLS. There did not appear to be any difference between these two conditions in the remaining transfer trials for this segment.

The ATARI covariate was moderately significant in the close-in segment and accounted for 10% of the between-subjects experimental variance.

RMS LINEUP ERROR. The only significant main effect for the transfer trials was that of FLOLS type in the middle segment (Table 3). RMS lineup error was lower for subjects trained with the RATE and CONVENTIONAL displays versus subjects trained with the COMMAND display. The Newman-Keuls Test for comparison of the mean differences between the RATE and COMMAND display and the CONVENTIONAL and COMMAND display approached significance at the .05 level. This effect accounted for 9% of the between-subjects experimental variance in the middle segment.

There was a significant FLOLS size by FLOLS type interaction for both segments (Table 3). Figure 18 indicates that subjects trained with the small FLOLS and RATE display had the lowest error scores. The FLOLS size by FLOLS type interactions accounted for an average of 12% of the between-subjects experimental variance.

There was a significant block by task interaction and block by FLOLS type interaction in the close-in segment (Table 3). As expected, subjects trained with the part task had higher error scores at the start of transfer, but rapidly improved their performances close to those of the whole-trained subjects (Figure 19-A). In the block by FLOLS type interaction, subjects trained with the COMMAND and CONVENTIONAL displays had high error scores at the start of transfer, whereas subjects trained with the RATE display showed good transfer performance immediately (Figure 19-B). However, after only a few trials, all groups were performing well.

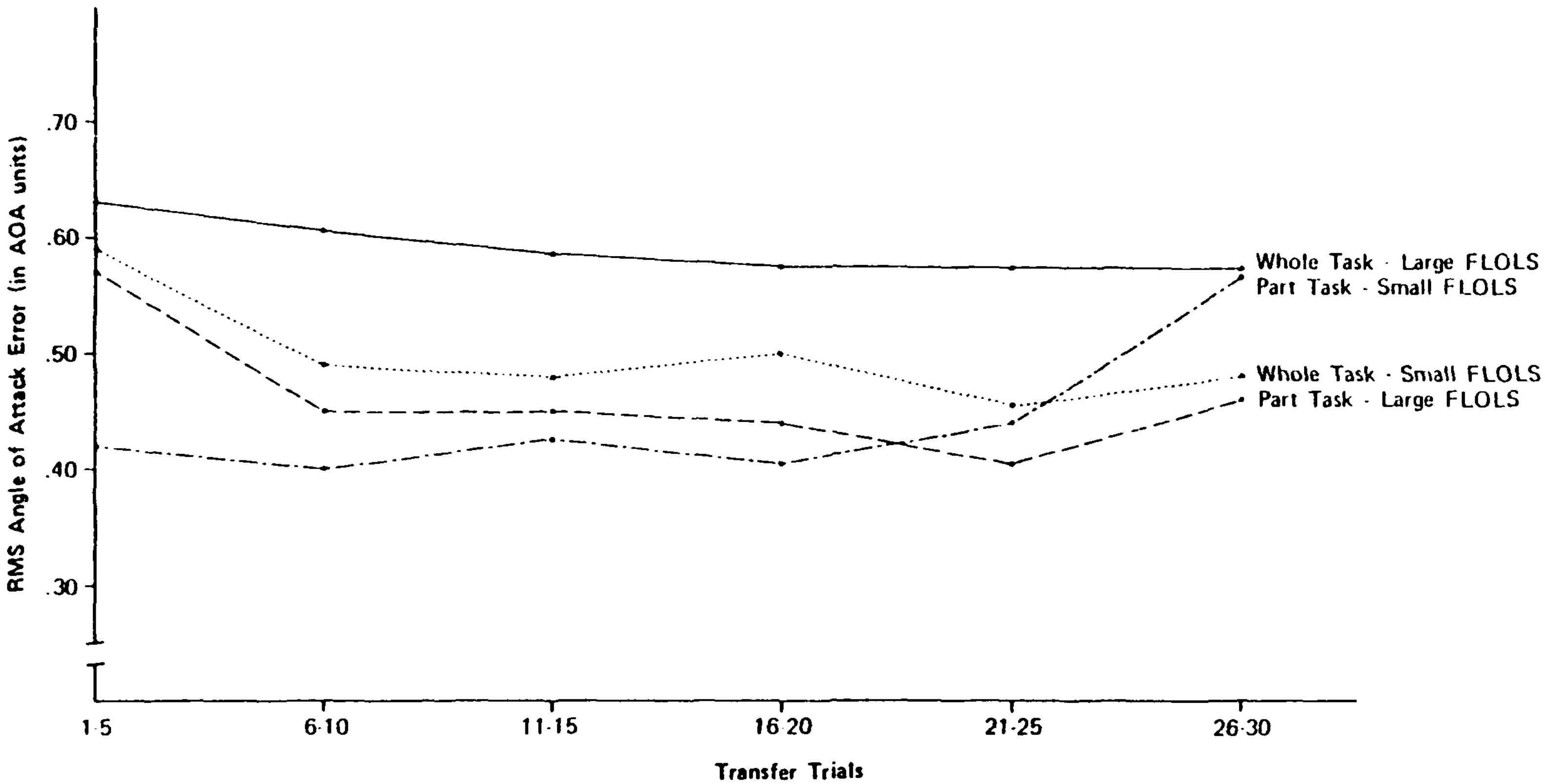


Figure 17. Block x task x FLOLS size interaction of RMS angle-of-attack error for the middle segment during transfer.

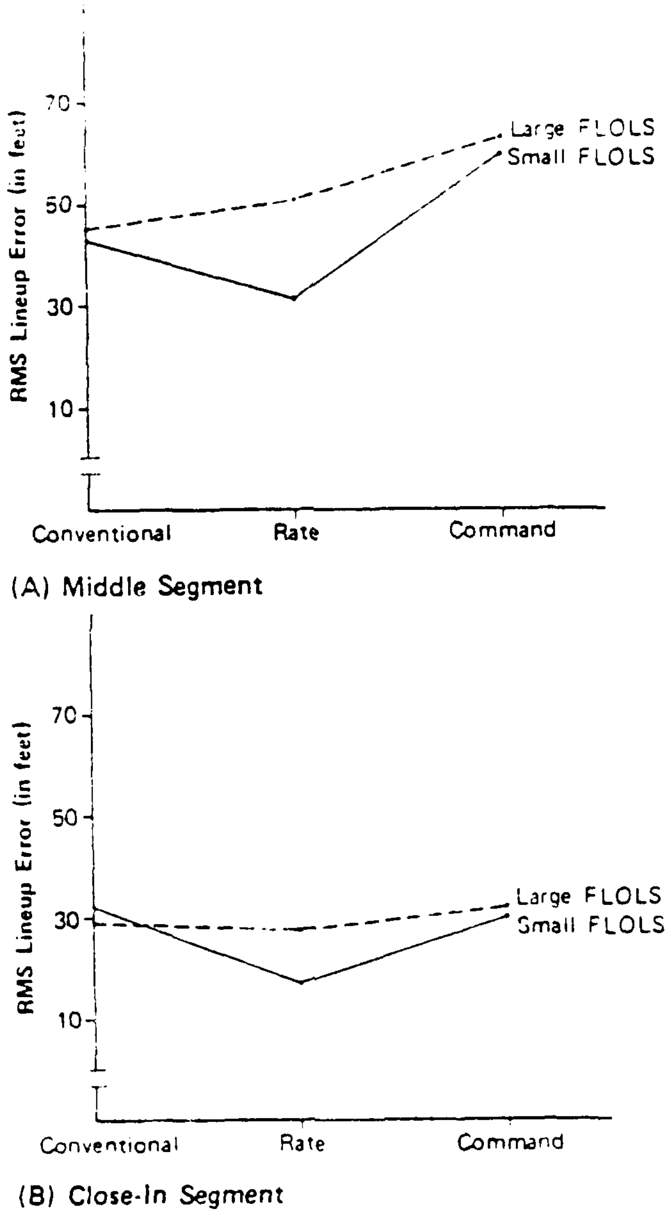


Figure 18. FLOLS size x FLOLS type interactions for RMS lineup error during transfer.

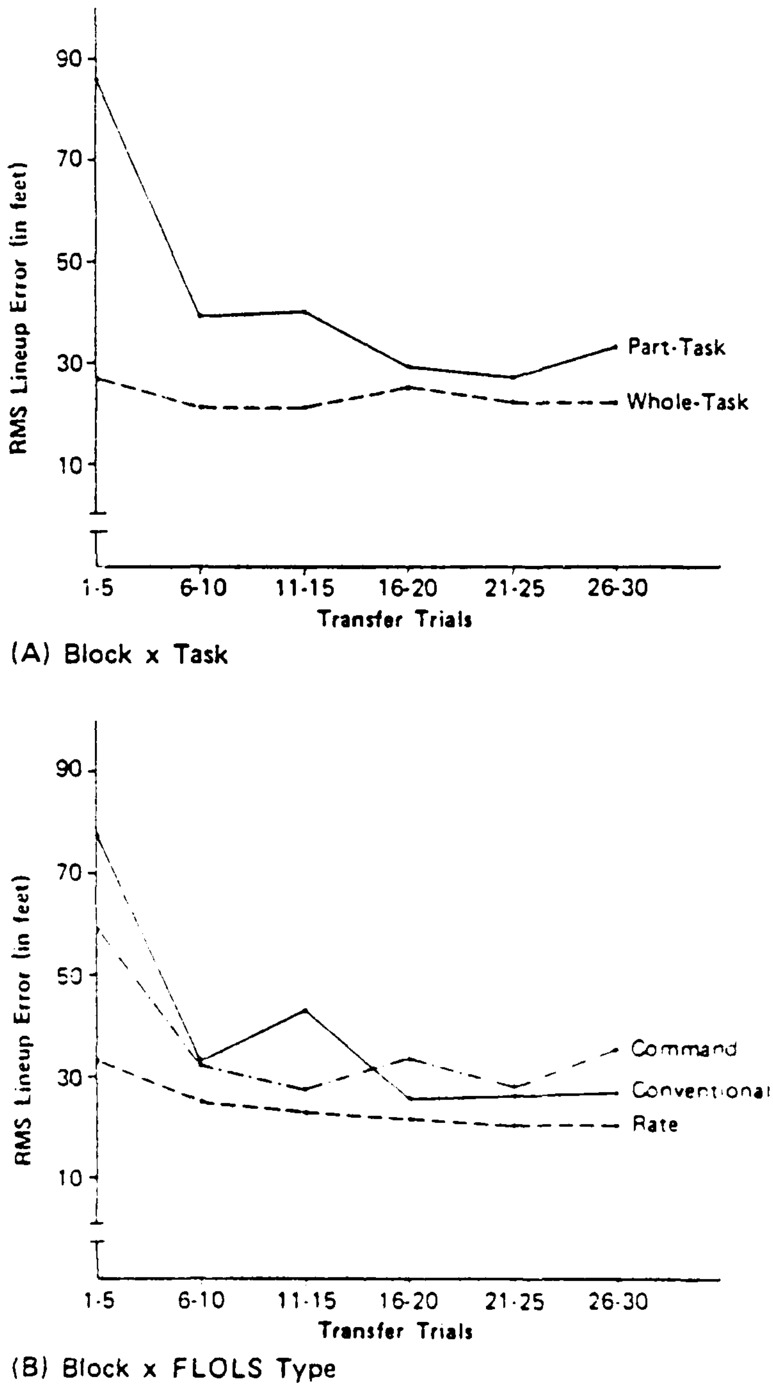


Figure 19. Block x task and block x FLOLS type interactions of RMS lineup error for the close-in segment during transfer.

The ATARI covariate was highly significant and accounted for an average of 27% of the between-subjects experimental variance in the segments.

SECTION IV

DISCUSSION

Of the two sets of data provided by a transfer-of-training study, only the transfer set provides evidence of differential training effectiveness. As argued by Salmoni, Schmidt, and Walter (1984), trends in the training data may be the result of transient performance effects, and may not reflect any relatively permanent differences in learning. The training data are discussed here specifically to ensure that they follow a reasonable pattern, and because the trends may assist in the explanation of trends in the transfer data. Thus, the following discussion of differential training effectiveness will rely primarily on the transfer data.

TRAINING PERFORMANCE

Substantial learning occurred in the training phase of the experiment as evidenced by the reliable block (learning) effects and the amount of variance accounted for by these effects for all measures of performance.

TASK EFFECT. There was no difference between training performance of the part-task and the whole-task groups on any glideslope measures of performance. Hence, the part-task method appears to have been successful in providing an effective (although not superior) learning environment for glideslope tracking.

Training performance of the part-task subjects versus whole-task subjects was reliably better on angle-of-attack control. This may have been the result of the greater demand on attitude control for the part-task group. The view of the carrier in the part-task condition was slightly different as a result of the need to start with and to maintain zero vertical velocity to stay on glideslope. As it took less attitude change in the part-task condition as opposed to the whole-task condition to lose sight of the aircraft carrier beneath the nose of the cockpit, subjects may have tended to limit their attitude variation in the part-task condition.

FLOLS SIZE. The interaction of FLOLS size and task type was puzzling. The large FLOLS when used in the whole-task condition was effective in helping subjects learn glideslope tracking skills in the simulator more quickly. However, the large FLOLS was not as effective when used in the part-task condition. At present there is no obvious reason that part-task performance would be poorer with a large FLOLS than with a small FLOLS.

FLOLS TYPE. There were no reliable training advantages with either the RATE or COMMAND displays. These results are surprising considering both the RATE and COMMAND display significantly improved glideslope tracking for experienced carrier pilots (Kaul et al., 1981). However, they are consistent with data from Westra (1982) who also found no training advantage with the COMMAND display in early learning of the carrier-landing task. Thus, it appears that early glideslope tracking performance is limited by the students' ability to properly execute the control movements. Considerable experience, with a concomitant improvement in motor skill, seems necessary before the supplementary rate information can assist glideslope tracking performance.

TRANSFER PERFORMANCE

TASK TYPE. The results indicate that glideslope control following part-task training was not as accurate as it was after whole-task training. Transfer from the part task produced poor early transfer in relation to transfer from the whole task, and this disadvantage did not appear to be entirely overcome by the end of transfer. There was a three-way interaction which indicated that part-task practice with the RATE display and small FLOLS was as effective for glideslope control as was whole-task practice. However, while the power to test this overall interaction was adequate, there was not enough power to resolve its interpretation in relation to paired comparisons of cells. Nevertheless, the implications of this interaction are important and will be discussed in the following paragraphs together with other task-type trends.

The carrier landing task is difficult and requires high coordination of its motor components. Previous part-task research has indicated that a knowledge of component interaction is necessary to train a task with interdependent components. Briggs and Naylor (1962) argued that similarity to the transfer task is also needed for effective learning of complex tasks. Thus, the lack of similarity between training and transfer tasks may have contributed to the relative inefficiency of the part-task training schedule. However, trends in the data suggest that, in addition to the lack of similarity between training and transfer tasks, another factor related to the ability to make rate interpretations from the meatball may also have affected transfer performance.

As noted previously, the FLOLS display is less than optimum because the error information from the meatball is of zero-order (displacement only). However, the linear gain of the FLOLS display changes along the approach to the carrier so that the meatball becomes much more sensitive to glideslope error in the close-in segment. Consequently, some judgement of the rate of movement of the meatball is possible, especially in the final part of the approach. In the part-task condition, subjects practiced glideslope control at only one point along the glideslope. While changes in display gain were not considered critical to learning, effective glideslope control, especially in the close-in segment, demands an awareness of anticipated meatball movement and appropriate control responses. The FLOLS display may not have been sensitive enough at the point at which the part-task subjects practiced glideslope control to enable effective learning of rate interpretation skills from the meatball. The glideslope control techniques that were learned were probably based primarily on displacement error. Thus, the part-task trained subjects may have been at a distinct disadvantage, at time of transfer, in relation to their ability to make judgments about rates of glideslope deviations.

The addition of the RATE display appears to have helped the part-task subjects, who trained with the small FLOLS, to follow the glideslope more accurately in the close-in segment. These subjects may have been able to learn some rate interpretation skills for transfer to the whole task. However, such an explanation does not suggest why part-task subjects trained with the large FLOLS did not similarly benefit from the addition of the RATE elements in training. Perhaps there is a confounding problem for part-task training with the RATE display and large FLOLS in transferring to the small FLOLS. Unfortunately, the statistical power for comparison of pairs of cells was not adequate to ascertain the reliability of this result.

As noted earlier, AOA control in training was better for part-trained subjects. This advantage carried over to early transfer, although the effect was brief and was statistically significant only for the middle segment on which the part subjects were trained. Nevertheless, this finding is encouraging for the part-task training strategy since AOA control is considered to be as important as glideslope control. A training strategy that could provide superior training on AOA control, along with adequate training on glideslope control for the carrier-landing task, would be beneficial.

As expected, a moderate amount of transition training in the whole task was sufficient to coordinate the skills essential for lateral control. In addition, it is expected that the amount of transition training to coordinate lateral control would be much less for students who have some flight experience.

In summary, the part-task training procedure tested here may be useful for glideslope tracking instruction if it can be less expensive than whole-task training. In addition, it did produce a brief and possibly useful enhancement of AOA. However, while the part-task training did provide some positive transfer in relation to glideslope tracking, it was not as efficient as whole-task training. The part-task training strategy might be further refined to provide better transfer in relation to glideslope tracking, possibly by positioning the simulated aircraft closer to the touchdown area or by manipulating the gain of the meatball. This technique offers some promise as a relatively inexpensive method for early carrier-landing training, although further research seems necessary to establish its value.

FLOLS TYPE. There were no significant differential transfer effects on RMS glideslope tracking after training with the CONVENTIONAL, RATE, or COMMAND displays. However, the improvement evident in transfer for all these groups was not as noticeable for the group trained with the COMMAND display. With this particular display it was possible to ignore the conventional displacement information entirely, so that subjects could have become dependent on the supplementary command information. Thus, some difficulty in transitioning to the CONVENTIONAL display would be expected if subjects had not learned to interpret the displacement information with reasonable efficiency, and this may account for the smaller improvement in transfer following training with the COMMAND display.

There were some minor differential transfer effects with other measures resulting from the use in training of the CONVENTIONAL, RATE, and COMMAND displays. AOA control was better following training with the COMMAND display and poorer following training with the RATE display. Subjects who learned with the COMMAND display apparently made glideslope corrections with power (correct procedure), while subjects trained with the RATE display seem to have preferred pitch corrections. While it is easier to track glideslope by adjusting pitch attitude, it is not the correct technique for carrier landings. Pitch adjustments for glideslope tracking are not only dangerous in-close, but can lead to incorrect airspeed and pitch attitude at touchdown, both of which can result in structural damage to the aircraft.

There was a marked increase in AOA error for the COMMAND trained group at the end of transfer. This indicates that for some unexpected reason, subjects started using more pitch adjustments to track glideslope. This large increase in AOA error is inconsistent with the rest of the transfer data and may have been a result of fatigue. It is, however, difficult to suggest why only one group would suffer the effects of fatigue at this point.

Some differential transfer effects were also apparent with average glideslope error. Subjects tended to fly above the glideslope in early transfer trials and this tendency was more extreme after training with the CONVENTIONAL and COMMAND displays than after training with the RATE display. This bias does not necessarily reflect a difference in overall performance quality, but it may be important from an operational viewpoint because higher approaches often result in a bolter. Thus, RATE training seems to offer the benefit of discouraging high approaches.

The concept of reduced workload would suggest that if a first-order display assisted glideslope control, it may also assist lineup control because the subject could divert some of his attention to lineup control (Kaul et al., 1980). The RATE display did encourage better lineup control although this effect again occurred only in early transfer trials. However, there was a lineup problem in the middle segment for subjects trained with the COMMAND display. The COMMAND display may have attracted more than its share of attention to the detriment of lineup, although this was not apparent in the training data. Lineup control was better for the COMMAND display in the close-in segment, but in an operational environment, a large lineup error in the middle segment is to be avoided because it may result in a wave off prior to reaching the close-in segment.

In summary, although there were some differential transfer effects resulting from the use in training of the RATE and COMMAND displays, there was not a significant performance advantage in glideslope control with either display. Previous research at the VTRS had shown a significant performance advantage in glideslope control for experienced pilots using the COMMAND and RATE displays (Kaul et al., 1980). However, subsequent research at the VTRS found no performance or transfer advantage with the COMMAND display for pilots who were taught carrier landing in the simulator (Westra, 1981). Thus, either pilots who are in the early stages of learning the carrier landing task do not benefit from the command display or the proper method of using it in training has not been found. RATE and COMMAND training did have some minor benefits on average glideslope error and on RMS AOA error. This raises the possibility that these displays might be used for remedial correction of specific bad habits. However, further evaluation of these displays is needed to thoroughly define their training value. For the present, it is suggested that the RATE and COMMAND displays should not be introduced to pilots until they have become carrier qualified with the conventional FLOLS.

FLOLS SIZE. Transition from a large to a small FLOLS produced no significant advantages or disadvantages on glideslope dimensions of performance. While there were some significant interaction effects from comparing trial blocks 6-10 and 21-25 for RMS glideslope error, they appear to be unimportant for training issues. Since there were no apparent negative effects in initial transfer from large to small FLOLS, and the interactions were weak, the significant effects were not judged to be operationally important.

There were some AOA effects resulting from the manipulation of FLOLS size. These effects were inconsistent across segments, with transition from the large FLOLS producing relatively poor

AOA control scores in the middle segment in early transfer, but relatively good AOA control scores in the close-in segment in later transfer. Thus, there may be a short-lived problem for AOA control in transfer following the use of a large FLOLS in training, but this would appear to be outweighed by the longer term benefit that is evident with the crucial close-in segment.

In summary, transfer from a large to a small FLOLS had no detrimental effects on glideslope performance, but there were some effects on AOA control. Overall, these effects were considered to favor training with the large FLOLS, but there may be a possible difficulty early in transfer. However, Navy flight students are likely to understand the need for good AOA control far better than did the college students used in this experiment, and sufficient care during instruction should avoid any possible negative consequences from instruction with a large FLOLS. Thus, it is concluded that the larger FLOLS can provide satisfactory training for the carrier landing task.

SECTION V

CONCLUSIONS

A quasi-transfer-of-training study was conducted with 36 flight-naive subjects to investigate a segmentation method of part-task training and two methods of visual augmentation for teaching simulated carrier landings. One visual enhancement involved adding two types of descent rate information (designated RATE and COMMAND) to the FLOLS display. The other visual enhancement was enlargement of the FLOLS display. The experimental sequence consisted of 30 training trials with instructional feedback under a particular experimental condition, followed by 30 test trials with no instructional feedback under the criterion condition (whole task with conventional and small FLOLS).

The segmentation method of part-task training used here was not as effective as was whole-task training. However, the part-task manipulation was extreme, and apparently was less effective because students were unable to practice some critical dimensions of the task. Nevertheless, part-task subjects did learn some skills that could be applied to the whole task. There is also a realistic possibility that some adjustments in the way the part-task procedure is set up would further enhance its effectiveness. Further development may permit this procedure to be as effective as the backward chaining method of part training that has been shown to be very effective for carrier-landing instruction (Wightman, 1983). Thus, part-task training shows promise as an effective training technique for the carrier-landing tasks, particularly considering the fact that it would permit the use of a relatively inexpensive training device.

Previous studies at the VTRS had shown a significant performance advantage in glideslope control with the COMMAND and RATE displays for experienced carrier pilots, but no performance of transfer advantage for student pilots who were taught carrier landings in the simulator. The strong performance advantage for experienced pilots had prompted a further test of the training effectiveness of the two special FLOLS displays. In spite of some variations in experimental procedures, the results were essentially similar to those of the previous training study. There is apparently no general performance or training benefit from the RATE or the COMMAND display with flight-naive subjects or with pilots who have no prior carrier landing experience. There were, however, some minor differential transfer effects resulting from the use in training of the CONVENTIONAL, RATE, and COMMAND displays. These might be useful in special remedial situations and may have some implications for the way these displays are introduced into the fleet as permanent guidance systems. For the present, it is suggested that the RATE and COMMAND display should not be introduced to pilots until they have become carrier qualified with the conventional FLOLS.

Possibly, the most important finding of this study is that transfer from a large to a small FLOLS has no general detrimental effects. Representation of the FLOLS is a critical element of a carrier landing trainer, and could add substantially to the cost of the simulator. The fact that a larger FLOLS can provide satisfactory training will permit a less expensive approach to simulating the FLOLS. A possible difficulty with AOA control in early transfer was noted, but sufficient care in training should overcome this potential problem.

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APPENDIX A

POWER ANALYSIS

TABLE A-1. PROBABILITY OF DETECTING SMALL, MEDIUM AND LARGE EFFECTS OF RMS GLIDESLOPE ERROR FOR THE MIDDLE AND CLOSE-IN SEGMENTS

Middle Segment

	Effect Size		
	Small	Medium	Large
RMS Glideslope Error	1.36	2.72	6.16
		Power	
Alpha .05	.11	.27	.84
Level .10	.18	.40	.92

Close-In Segment

	Effect Size		
	Small	Medium	Large
RMS Glideslope Error	.70	1.42	3.19
		Power	
Alpha .05	.09	.22	.74
Level .10	.16	.33	.85

APPENDIX B

TRAINING DATA SUMMARY TABLES

TABLE B-1. REPEATED MEASURES ANALYSIS OF COVARIANCE OF RMS GLIDESLOPE ERROR FOR THE MIDDLE SEGMENT DURING TRAINING

Source of Variance	Sum of Squares	df	Mean Squares	F	Proportion of Variance
Between Factor					
Task (Ta)	.219	1	.219	.62	NS
FLOLS Size (FS)	.204	1	.204	.58	NS
FLOLS Type (FT)	.539	2	.270	.76	NS
Ta x FS	1.433	1	1.433	4.06*	.11
Ta x FT	.820	2	.410	1.16	NS
FS x FT	.765	2	.382	1.08	NS
Ta x FS x FT	.473	2	.236	.67	NS
Covariate	1.02	1	1.022	2.90	NS
Error	8.110	23	.353		
Within Factor					
Blocks (B)	3.675	5	.735	27.89***	.41
B x Ta	.166	5	.033	1.26	NS
B x FS	.233	5	.047	1.77	NS
B x FT	.163	10	.016	.62	NS
B x Ta x FS	.449	5	.090	3.41***	.05
B x Ta x FT	.183	10	.018	.70	NS
B x FS x FT	.701	10	.070	2.66***	.08
B x Ta x FS x FT	.228	10	.023	.86	NS
Error	3.162	120	.026		

*:P<.10
**:P<.05
***:P<.01

TABLE B-2. REPEATED MEASURES ANALYSIS OF COVARIANCE OF RMS GLIDESLOPE ERROR FOR THE CLOSE-IN SEGMENT DURING TRAINING

Source of Variance	Sum of Squares	df	Mean Squares	F	Proportion of Variance
Between Factor					
Task (Ta)	.082	1	.082	.21	NS
FLOLS Size (FS)	.044	1	.044	.11	NS
FLOLS Type (FT)	.402	2	.201	.51	NS
Ta x FS	1.574	1	1.574	4.00*	.10
Ta x FT	1.329	2	.665	1.69	NS
FS x FT	.722	2	.361	.92	NS
Ta x FS x FT	1.124	2	.562	1.43	NS
Covariate	.744	1	.744	1.89	NS
Error	9.053	23	.394		
Within Factor					
Blocks (B)	4.804	5	.961	39.23***	.52
B x Ta	.174	5	.035	1.42	NS
B x FS	.178	5	.036	1.45	NS
B x FT	.231	10	.023	.94	NS
B x Ta x FS	.128	5	.026	1.04	NS
B x Ta x FT	.320	10	.032	1.31	NS
B x FS x FT	.378	10	.038	1.54	NS
B x Ta x FS x FT	.147	10	.015	.60	NS
Error	2.939	120	.024		

*: $p < .10$
**: $p < .05$
***: $p < .01$

TABLE B-3. REPEATED MEASURES ANALYSIS OF COVARIANCE OF AVERAGE GLIDESLOPE ERROR FOR THE MIDDLE SEGMENT DURING TRAINING

Source of Variance	Sum of Squares	df	Mean Squares	F	Proportion of Variance
<u>Between</u> <u>Factor</u>					
Task (Ta)	1817	1	1817	1.64	NS
FLOLS Size (FS)	417	1	417	.38	NS
FLOLS Type (FT)	1412	2	706	.64	NS
Ta x FS	5256	1	5256	4.76**	.13
Ta x FT	218	2	109	.10	NS
FS x FT	4396	2	2198	1.99	NS
Ta x FS x FT	66	2	33	.03	NS
Covariate	64	1	64	.06	NS
Error	25426	23	1105		
<u>Within</u> <u>Factor</u>					
Blocks (B)	41696	5	8339	11.91***	.25
B x Ta	3957	5	791	1.13	NS
B x FS	1949	5	389	.56	NS
B x FT	5360	10	536	.77	NS
B x Ta x FS	7901	5	1580	2.26*	.05
B x Ta x FT	6631	10	663	.95	NS
B x FS x FT	5981	10	598	.85	NS
B x Ta x FS x FT	8808	10	880	1.26	NS
Error	84000	120	700		

*:P<.10
**:P<.05
***:P<.01

TABLE B-4. REPEATED MEASURES ANALYSIS OF COVARIANCE OF AVERAGE GLIDESLOPE ERROR FOR THE CLOSE-IN SEGMENT DURING TRAINING

Source of Variance	Sum of Squares	df	Mean Squares	F	Proportion of Variance
Between Factor					
Task (Ta)	1347	1	1347	.80	NS
FLOLS Size (FS)	14	1	14	.01	NS
FLOLS Type (FT)	4396	2	2198	1.31	NS
Ta x FS	7808	1	7808	4.64**	.14
Ta x FT	21	2	11	.01	NS
FS x FT	3045	2	1522	.90	NS
Ta x FS x FT	674	2	337	.20	NS
Covariate	250	1	256	.15	NS
Error	38694	23	1682		
Within Factor					
Blocks (B)	61468	5	12293	12.02***	.25
B x Ta	5211	5	1042	1.02	NS
B x FS	3507	5	701	.69	NS
B x FT	15885	10	1588	1.55	NS
B x Ta x FS	16118	5	3223	3.15**	.07
B x Ta x FT	5385	10	538	.53	NS
B x FS x FT	8022	10	802	.78	NS
B x Ta x FS x FT	6342	10	634	.62	NS
Error	122727	120	1022		

*: $p<.10$
**: $p<.05$
***: $p<.01$

TABLE B-5. REPEATED MEASURES ANALYSIS OF COVARIANCE OF RMS ANGLE-OF-ATTACK ERROR FOR THE MIDDLE SEGMENT DURING TRAINING

Source of Variance	Sum of Squares	df	Mean Squares	F	Proportion of Variance
Between Factor					
Task (Ta)	.1869	1	.1869	6.23**	.17
FLOLS Size (FS)	.0018	1	.1869	.06	NS
FLOLS Type (FT)	.0281	2	.0140	.47	NS
Ta x FS	.0057	1	.0057	.19	NS
Ta x FT	.0679	2	.0339	1.13	NS
FS x FT	.0099	2	.0049	.16	NS
Ta x FS x FT	.0869	2	.0435	1.45	NS
Covariate	.0002	1	.0002	.01	NS
Error	.6902	23	.0300		
Within Factor					
Blocks (B)	.1288	5	.0258	9.07***	.20
B x Ta	.0313	5	.0063	2.20*	.05
B x FS	.0041	5	.0008	.29	NS
B x FT	.0129	10	.0013	.46	NS
B x Ta x FS	.0105	5	.0021	.74	NS
B x Ta x FT	.0251	10	.0025	.88	NS
B x FS x FT	.0757	10	.0076	2.67***	.12
B x Ta x FS x FT	.0243	10	.0024	.86	NS
Error	.3407	120	.0028		

*: $p < .10$
**: $p < .05$
***: $p < .01$

TABLE B-6. REPEATED MEASURES ANALYSIS OF COVARIANCE OF RMS ANGLE-OF-ATTACK ERROR FOR THE CLOSE-IN SEGMENT DURING TRANING

Source of Variance	Sum of Squares	df	Mean Squares	F	Proportion of Variance
Between Factor					
Task (Ta)	.4012	1	.4012	11.53***	.27
FLOLS Size (FS)	.0001	1	.0001	.00	NS
FLOLS Type (FT)	.0433	2	.0216	.62	NS
Ta x FS	.0002	1	.0002	.00	NS
Ta x FT	.0681	2	.0340	.98	NS
FS x FT	.0147	2	.0074	.21	NS
Ta x FS x FT	.1227	2	.0614	1.76	NS
Covariate	.0238	1	.0238	.68	NS
Error	.8001	23	.0348		
Within Factor					
Blocks (B)	.1931	5	.0386	10.44***	.23
B x Ta	.0288	5	.0058	1.56	NS
B x FS	.0043	5	.0009	.23	NS
B x FT	.0270	10	.0027	.73	NS
B x Ta x FS	.0112	5	.0022	.60	NS
B x Ta x FT	.0142	10	.0014	.38	NS
B x FS x FT	.0831	10	.0083	2.25**	.10
B x Ta x FS x FT	.0186	10	.0019	.50	NS
Error	.4442	120	.0037		

*:p<.10
**:p<.05
***:p<.01

TABLE B-7. MEAN GLIDESLOPE RMS ERROR (IN FEET) FOR THE MIDDLE SEGMENT DURING TRAINING

Trial Means	1-5	6-10	11-15	16-20	21-25	26-30
Task (Ta)						
Whole	74.9	32.0	23.7	24.1	22.3	17.4
Part	56.1	37.2	27.0	16.4	15.3	15.8
FLOLS Size (FS)						
Small	65.2	34.3	21.1	20.1	18.5	17.4
Large	65.9	35.0	29.6	20.5	19.2	15.8
FLOLS Type (FT)						
Conventional (Cv)	58.9	35.5	26.7	18.1	14.1	13.5
Rate (Ra)	78.5	32.4	23.1	18.7	17.9	16.6
Command (Cm)	59.5	36.0	26.3	24.0	24.4	19.7

TABLE B-8. MEAN GLIDESLOPE RMS ERROR (IN FEET) FOR THE CLOSE-IN SEGMENT DURING TRAINING

Trial Means	1-5	6-10	11-15	16-20	21-25	26-30
Task (Ta)						
Whole	75.8	24.3	19.7	17.6	16.0	12.2
Part	68.2	46.4	26.6	16.7	16.6	16.9
FLOLS Size (FS)						
Small	67.1	34.6	22.0	19.0	16.6	14.1
Large	77.0	36.1	24.3	15.3	16.1	14.9
FLOLS Type (FT)						
Conventional (Cv)	72.8	37.8	28.6	15.6	13.0	13.1
Rate (Ra)	90.4	30.5	18.4	15.9	15.9	14.4
Command (Cm)	53.3	37.6	22.4	19.9	20.0	16.1

TABLE B-9. *MEAN AVERAGE GLIDESLOPE ERROR (IN FEET, + = HIGH)* FOR THE MIDDLE SEGMENT DURING TRAINING

Trial Means	1-5	6-10	11-15	16-20	21-25	26-30
Task (Ta)						
Whole	52.9	17.6	9.2	7.8	1.4	1.6
Part	29.2	14.9	10.5	1.3	1.3	- .7
FLOLS Size (FS)						
Small	40.3	21.0	6.5	6.3	6.5	.9
Large	41.9	11.5	13.2	2.8	-3.7	- .1
FLOLS Type (FT)						
Conventional (Cv)	39.3	19.2	13.5	.4	3.0	-1.1
Rate (Ra)	56.8	20.8	5.5	8.1	1.5	.1
Command (Cm)	27.5	8.8	10.6	5.3	-.4	2.3

TABLE B-10. MEAN AVERAGE GLIDESLOPE ERROR (IN FEET, + = HIGH) FOR THE CLOSE-IN SEGMENT DURING TRAINING

5-Trial Means	1-5	6-10	11-15	16-20	21-25	26-30
Task (Ta)						
Whole	61.9	13.9	9.0	9.2	3.5	2.5
Part	38.4	21.6	10.8	3.9	1.8	-3.2
FLOLS Size (FS)						
Small	41.4	17.2	9.0	9.8	5.4	- .6
Large	58.9	18.3	10.8	3.3	- .1	- .2
FLOLS Type (FT)						
Conventional (Cv)	56.4	25.4	18.9	5.9	2.8	-1.5
Rate (Ra)	74.7	13.8	4.2	8.1	2.8	1.7
Command (Cm)	19.9	14.1	6.5	5.7	2.4	-1.3

TABLE B-11. MEAN ANGLE-OF-ATTACK RMS ERROR (IN AOA UNITS) FOR THE MIDDLE SEGMENT DURING TRAINING

5-Trial Means	1-5	6-10	11-15	16-20	21-25	26-30
Task (Ta)						
Whole	.754	.716	.607	.601	.621	.546
Part	.811	.642	.478	.327	.291	.322
FLOLS Size (FS)						
Small	.791	.656	.583	.481	.450	.459
Large	.775	.702	.502	.446	.462	.409
FLOLS Type (FT)						
Conventional (Cv)	.720	.716	.523	.410	.353	.403
Rate (Ra)	.715	.540	.459	.438	.409	.401
Command (Cm)	.912	.781	.645	.543	.606	.498

TABLE B-12. MEAN ANGLE-OF-ATTACK RMS ERROR (IN AOA UNITS) FOR THE CLOSE-IN SEGMENT DURING TRAINING

5-Trial Means	1-5	6-10	11-15	16-20	21-25	26-30
Task (Ta)						
Whole	1.05	.845	.755	.747	.899	.663
Part	.838	.717	.469	.321	.302	.345
FLOLS Size (FS)						
Small	.956	.750	.709	.523	.607	.536
Large	.934	.813	.515	.544	.594	.472
FLOLS Type (FT)						
Conventional (Cv)	.946	.834	.457	.441	.401	.460
Rate (Ra)	.954	.634	.589	.488	.630	.499
Command (Cm)	.934	.876	.791	.673	.769	.552

APPENDIX C

TRANSFER DATA SUMMARY TABLES

TABLE C-1. REPEATED MEASURES ANALYSIS OF COVARIANCE OF RMS GLIDESLOPE ERROR FOR THE MIDDLE SEGMENT DURING TRANSFER

Source of Variance	Sum of Squares	df	Mean Squares	F	Proportion of Variance
Between Factor					
Task (Ta)	.657	1	.657	4.90**	.13
FLOLS Size (FS)	.070	1	.070	.52	NS
FLOLS Type (FT)	.112	2	.056	.42	NS
Ta x FS	.020	1	.020	.15	NS
Ta x FT	.439	2	.219	1.64	NS
FS x FT	.193	2	.096	.72	NS
Ta x FS x FT	.322	2	.161	1.20	NS
Covariate	.100	1	.100	.75	NS
Error	3.085	23	.134		
Within Factor					
Blocks (B)	1.087	5	.217	9.54***	.21
B x Ta	.302	5	.060	2.65**	.06
B x FS	.131	5	.026	1.15	NS
B x FT	.152	10	.015	.67	NS
B x Ta x FS	.040	5	.008	.35	NS
B x Ta x FT	.424	10	.042	1.86*	.08
B x FS x FT	.187	10	.019	.82	NS
B x Ta x FS x FT	.171	10	.017	.75	NS
Error	2.734	120	.023		

*:P<.10
**:P<.05
***:P<.01

TABLE C-2. REPEATED MEASURES ANALYSIS OF COVARIANCE OF RMS GLIDESLOPE ERROR FOR THE CLOSE-IN SEGMENT DURING TRANSFER

Source of Variance	Sum of Squares	df	Mean Squares	F	Proportion of Variance
Between Factor					
Task (Ta)	.550	1	.550	4.69**	.10
FLOLS Size (FS)	.000	1	.000	.00	NS
FLOLS Type (FT)	.193	2	.096	.82	NS
Ta x FS	.010	1	.010	.09	NS
Ta x FT	.156	2	.078	.66	NS
FS x FT	.094	2	.047	.40	NS
Ta x FS x FT	.853	2	.426	3.64**	.15
Covariate	1.061	1	1.061	9.05***	.19
Error	2.695	23	.117		
Within Factor					
Blocks (B)	1.923	5	.385	19.24***	.35
B x Ta	.329	5	.066	3.29***	.07
B x FS	.105	5	.021	1.05	NS
B x FT	.270	10	.027	1.35	NS
B x Ta x FS	.053	5	.011	.54	NS
B x Ta x FT	.218	10	.022	1.09	NS
B X FS X FT	.113	10	.011	.56	NS
B x Ta x FS x FT	.084	10	.008	.42	NS
Error	2.398	120	.020		

*:p<.10
**:p<.05
***:p<.01

TABLE C-3. REPEATED MEASURES ANALYSIS OF COVARIANCE OF AVERAGE GLIDESLOPE ERROR FOR THE MIDDLE SEGMENT DURING TRANSFER

Source of Variance	Sum of Squares	df	Mean Squares	F	Proportion of Variance
Between Factor					
Task (Ta)	7706	1	7706	9.58***	.23
FLOLS Size (FS)	179	1	179	.22	NS
FLOLS Type(FT)	2330	2	1165	1.45	NS
Ta x FS	17	1	17	.02	NS
Ta x FT	1919	2	960	1.19	NS
FS x FT	917	2	459	.57	NS
Ta x FS x FT	947	2	474	.59	NS
Covariate	354	1	355	.44	NS
Error	18493	23	804		
Within Factor					
Blocks (B)	6175	5	1235	5.71***	.13
B x Ta	6696	5	1339	6.19***	.14
B x FS	817	5	163	.76	NS
B x FT	1800	10	180	.83	NS
B x Ta x FS	445	5	89	.41	NS
B x Ta x FT	2128	10	212	.98	NS
B x FS x FT	1666	10	167	.77	NS
B x Ta x FS x FT	1201	10	120	.56	NS
Error	25945	120	216		

*:p<.10
**:p<.05
***:p<.01

TABLE C-4. REPEATED MEASURES ANALYSIS OF COVARIANCE OF AVERAGE GLIDESLOPE ERROR FOR THE CLOSE-IN SEGMENT DURING TRANSFER

Source of Variance	Sum of Squares	df	Mean Squares	F	Proportion of Variance
Between Factor					
Task (Ta)	2498	1	2498	4.17*	.12
FLOLS Size (FS)	5	1	5	.01	NS
FLOLS Type (FT)	1121	2	560	.94	NS
Ta x FS	545	1	545	.91	NS
Ta x FT	496	2	248	.41	NS
FS x FT	297	2	149	.25	NS
Ta x FS x FT	892	2	446	.74	NS
Covariate	421	1	421	.70	NS
Error	13766	23	599		
Within Factor					
Blocks (B)	8020	5	1604	8.18***	.18
B x Ta	4853	5	970	4.95***	.11
B x FS	533	5	107	.54	NS
B x FT	1912	10	191	.97	NS
B x Ta x FS	923	5	185	.94	NS
B x Ta x FT	2370	10	237	1.21	NS
B x FS x FT	938	10	94	.48	NS
B x Ta x FS x FT	726	10	73	.37	NS
Error	23543	120	196		

*:p<.10
**:p<.05
***:p<.01

TABLE C-5. REPEATED MEASURES ANALYSIS OF COVARIANCE OF RMS ANGLE-OF-ATTACK ERROR FOR THE MIDDLE SEGMENT DURING TRANSFER

Source of Variance	Sum of Squares	df	Mean Squares	F	Proportion of Variance
Between Factor					
Task (Ta)	.0357	1	.0357	1.57	NS
FLOLS Size (FS)	.0121	1	.0121	.53	NS
FLOLS Type (FT)	.0491	2	.0245	1.08	NS
Ta x FS	.0037	1	.0037	.16	NS
Ta x FT	.0287	2	.0143	.63	NS
FS x FT	.0046	2	.0023	.10	NS
Ta x FS x FT	.0353	2	.0177	.78	NS
Covariate	.0037	1	.0037	.16	NS
Error	.5227	23	.0227		
Within Factor					
Blocks (B)	.0124	5	.0024	4.72***	.10
B x Ta	.0051	5	.0010	1.93*	.04
B x FS	.0045	5	.0009	1.72	NS
B x FT	.0127	10	.0013	2.43**	.10
B x Ta x FS	.0084	5	.0017	3.21***	.07
B x Ta x FT	.0045	10	.0004	.86	NS
B x FS x FT	.0068	10	.0007	1.29	NS
B x Ta x FS x FT	.0085	10	.0009	1.62	NS
Error	.0629	120	.0005		

*:p<.10
**:p<.05
***:p<.01

TABLE C-6. REPEATED MEASURES ANALYSIS OF COVARIANCE OF RMS ANGLE-OF-ATTACK ERROR FOR THE CLOSE-IN SEGMENT DURING TRANSFER

Source of Variance	Sum of Squares	df	Mean Squares	F	Proportion of Variance
Between Factor					
Task (Ta)	.0116	1	.0116	.54	NS
FLOLS Size (FS)	.0017	1	.0017	.08	NS
FLOLS Type (FT)	.0482	2	.0241	1.12	NS
Ta x FS	.0011	1	.0011	.05	NS
Ta x FT	.0071	2	.0035	.16	NS
FS x FT	.0197	2	.0099	.46	NS
Ta x FS x FT	.0407	2	.0204	.95	NS
Covariate	.0687	1	.0687	3.20*	.10
Error	.4939	23	.0215		
Within Factor					
Blocks (B)	.0199	5	.0040	2.23*	.05
B x Ta	.0054	5	.0011	.61	NS
B x FS	.0166	5	.0033	1.87	NS
B x FT	.0223	10	.0022	1.25	NS
B x Ta x FS	.0199	5	.0040	2.24*	.05
B x Ta x FT	.0213	10	.0021	1.20	NS
B x FS x FT	.0238	10	.0024	1.34	NS
B x Ta x FS x FT	.0202	10	.0020	1.14	NS
Error	.2134	120	.0018		

*: $p < .10$
**: $p < .05$
***: $p < .01$

TABLE C-7. REPEATED MEASURES ANALYSIS OF COVARIANCE OF RMS *LINEUP ERROR FOR THE MIDDLE SEGMENT DURING TRANSFER*

Source of Variance	Sum of Squares	df	Mean Squares	F	Proportion of Variance
Between Factor					
Task (Ta)	.003	1	.003	.01	NS
FLOLS Size (FS)	.157	1	.157	.82	NS
FLOLS Type (FT)	1.112	2	.556	2.91*	.09
Ta x FS	.067	1	.067	.35	NS
Ta x FT	.484	2	.242	1.27	NS
FS x FT	1.616	2	.808	4.23**	.14
Ta x FS x FT	.568	2	.284	1.49	NS
Covariate	3.416	1	3.416	17.91***	.29
Error	4.388	23	.191		
Within Factor					
Blocks (B)	.207	5	.041	1.16	NS
B x Ta	.153	5	.031	.86	NS
B x FS	.108	5	.022	.61	NS
B x FT	.326	10	.032	.92	NS
B x Ta x FS	.494	5	.099	2.78**	.07
B x Ta x FT	.175	10	.018	.49	NS
B x FS x FT	.481	10	.048	1.35	NS
B x Ta x FS x FT	.400	10	.040	1.13	NS
Error	4.268	120	.036		

*: $p < .10$
**: $p < .05$
***: $p < .01$

TABLE C-8. REPEATED MEASURES ANALYSIS OF COVARIANCE OF RMS LINEUP ERROR FOR THE CLOSE-IN SEGMENT DURING TRANSFER

Source of Variance	Sum of Squares	df	Mean Squares	F	Proportion of Variance
Between Factor					
Task (Ta)	.323	1	.323	1.41	NS
FLOLS Size (FS)	.209	1	.209	.91	NS
FLOLS Type (FT)	.735	2	.368	1.61	NS
Ta x FS	.019	1	.019	.08	NS
Ta x FT	.668	2	.334	1.46	NS
FS x FT	1.190	2	.595	2.60*	.10
Ta x FS x FT	.868	2	.434	1.90	NS
Covariate	3.101	1	3.101	13.55***	.25
Error	5.263	23	.229		
Within Factor					
Blocks (B)	.495	5	.099	4.25***	.10
B x Ta	.234	5	.047	2.01*	.05
B x FS	.128	5	.026	1.09	NS
B x FT	.447	10	.045	1.92**	.09
B x Ta x FS	.159	5	.032	1.36	NS
B x Ta x FT	.249	10	.025	1.07	NS
B x FS x FT	.297	10	.030	1.27	NS
B x Ta x FS x FT	.338	10	.034	1.45	NS
Error	2.798	120	.023		

*: $p<.10$
**: $p<.05$
***: $p<.01$

TABLE C-9. MEAN GLIDESLOPE RMS ERROR (IN FEET) FOR THE MIDDLE SEGMENT DURING TRANSFER

5-Trial Means	1-5	6-10	11-15	16-20	21-25	26-30
Task (Ta)						
Whole	23.4	20.5	20.4	21.2	16.6	15.2
Part	47.6	29.6	23.9	21.4	20.7	20.6
FLOLS Size (FS)						
Small	34.0	25.7	21.4	20.3	16.4	16.2
Large	37.0	24.4	22.8	22.3	21.0	19.5
FLOLS Type (FT)						
Conventional (Cv)	41.8	24.3	19.2	21.2	16.8	15.7
Rate (Ra)	30.3	24.5	21.3	19.2	19.1	17.3
Command (Cm)	34.4	26.3	25.9	23.5	20.1	20.7

TABLE C-10. MEAN GLIDESLOPE RMS ERROR (IN FEET)
FOR THE CLOSE-IN SEGMENT DURING TRANSFER

5-Trial Means	1-5	6-10	11-15	16-20	21-25	26-30
Task (Ta)						
Whole	17.7	12.8	14.4	13.2	10.6	11.1
Part	44.6	21.6	19.3	15.8	14.7	14.8
FLOLS Size (FS)						
Small	32.9	19.5	16.5	13.5	11.4	12.6
Large	29.3	14.9	17.2	15.5	13.8	13.4
FLOLS Type (FT)						
Conventional (Cv)	36.3	20.5	14.9	13.4	11.8	10.2
Rate (Ra)	25.1	15.5	15.3	13.8	11.6	11.4
Command (Cm)	32.1	15.7	20.3	15.8	14.4	17.4

TABLE C-11. MEAN AVERAGE GLIDESLOPE ERROR (IN FEET, + = HIGH) FOR THE MIDDLE SEGMENT DURING TRANSFER

5-Trial Means	1-5	6-10	11-15	16-20	21-25	26-30
Task (Ta)						
Whole	5.2	5.5	6.2	11.4	4.9	3.0
Part	39.1	20.9	17.8	11.4	8.8	8.4
FLOLS Size (FS)						
Small	20.2	13.6	14.4	11.2	4.8	2.0
Large	24.1	12.8	9.7	11.6	-8.9	9.3
FLOLS Type (FT)						
Conventional (Cv)	31.0	19.4	12.4	13.8	6.5	3.6
Rate (Ra)	13.5	6.1	7.7	8.0	3.1	5.8
Command (Cm)	22.0	14.1	15.9	12.5	10.9	7.7

TABLE C-12. MEAN AVERAGE GLIDESLOPE ERROR (IN FEET, + = HIGH) FOR THE CLOSE-IN SEGMENT DURING TRANSFER

5-Trial Means	1-5	6-10	11-15	16-20	21-25	26-30
Task (Ta)						
Whole	7.6	6.0	4.9	6.9	2.1	1.8
Part	36.0	12.1	9.6	5.7	6.4	6.1
FLOLS Size (FS)						
Small	22.7	10.6	8.4	5.9	2.3	1.3
Large	20.9	7.5	6.1	6.7	6.2	6.5
FLOLS Type (FT)						
Conventional (Cv)	28.8	16.3	7.3	5.9	4.1	1.6
Rate (Ra)	12.8	4.7	3.9	5.2	2.7	3.3
Command (Cm)	23.9	6.1	10.5	7.8	6.0	6.8

TABLE C-13. MEAN ANGLE-OF-ATTACK RMS ERROR (IN AOA UNITS) FOR THE MIDDLE SEGMENT DURING TRANSFER

5-Trial Means	1-5	6-10	11-15	16-20	21-25	26-30
Task (Ta)						
Whole	.611	.549	.533	.535	.510	.522
Part	.498	.426	.438	.423	.423	.508
FLOLS Size (FS)						
Small	.505	.446	.453	.454	.448	.518
Large	.603	.529	.517	.504	.485	.511
FLOLS Type (FT)						
Conventional (Cv)	.551	.540	.484	.501	.465	.472
Rate (Ra)	.634	.542	.578	.528	.522	.557
Command (Cm)	.478	.380	.393	.407	.413	.514

TABLE C-14. MEAN ANGLE-OF-ATTACK RMS ERROR (IN AOA UNITS) FOR THE CLOSE-IN SEGMENT DURING TRANSFER

5-Trial Means	1-5	6-10	11-15	16-20	21-25	26-30
Task (Ta)						
Whole	.778	.698	.644	.615	.649	.671
Part	.705	.617	.652	.652	.619	.721
FLOLS Size (FS)						
Small	.706	.624	.614	.617	.616	.776
Large	.777	.691	.682	.659	.651	.615
FLOLS Type (FT)						
Conventional (Cv)	.717	.629	.676	.685	.640	.623
Rate (Ra)	.899	.762	.693	.656	.675	.718
Command (Cm)	.607	.580	.576	.574	.586	.746

TABLE C-15. MEAN LINEUP RMS ERROR (IN FEET)
FOR THE MIDDLE SEGMENT DURING TRANSFER

5-Trial Means	1-5	6-10	11-15	16-20	21-25	26-30
Task (Ta)						
Whole	50.5	44.5	40.6	49.4	46.9	46.5
Part	90.7	55.3	60.1	47.5	43.5	54.9
FLOLS Size (FS)						
Small	63.4	49.2	45.8	39.4	40.7	49.1
Large	77.8	50.7	54.8	57.6	49.6	52.3
FLOLS Type (FT)						
Conventional (Cv)	84.7	44.2	57.9	39.5	40.7	40.5
Rate (Ra)	53.4	46.8	41.5	38.1	39.3	38.5
Command (Cm)	73.6	58.7	51.7	67.8	55.6	73.0

TABLE C-16. MEAN LINEUP RMS ERROR (IN FEET)
FOR THE CLOSE-IN SEGMENT DURING TRANSFER

5-Trial Means	1-5	6-10	11-15	16-20	21-25	26-30
Task (Ta)						
Whole	27.2	21.4	21.2	24.9	22.3	22.0
Part	85.9	39.0	40.6	28.8	27.4	32.9
FLOLS Size (FS)						
Small	51.9	32.0	28.8	21.5	24.1	25.7
Large	61.2	28.4	33.0	32.2	25.7	29.2
FLOLS Type (FT)						
Coventional (Cv)	77.1	32.6	42.9	25.0	26.3	26.7
Rate (Ra)	33.4	25.2	22.5	21.7	20.8	20.6
Command (Cm)	59.1	32.9	27.3	33.8	27.4	35.1

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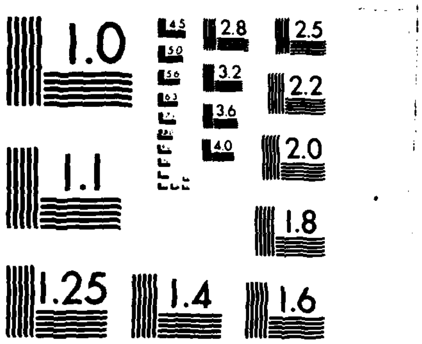

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